Northeast Fisheries Science Center Reference Document 13-10

56th Northeast Regional Stock Assessment Workshop (56th SAW)

Assessment Report

by the Northeast Fisheries Science Center

June 2013

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NOAA's National Marine Fisheries Serv., 166 Water St., Woods Hole MA 02543

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

June 2013

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Foreword

The Northeast Regional Stock Assessment Workshop (SAW) process has three parts: preparation of stock assessments by the SAW Working Groups and/or by ASMFC Technical Committees / Assessment Committees; peer review of the assessments by a panel of outside experts who judge the adequacy of the assessment as a basis for providing scientific advice to managers; and a presentation of the results and reports to the Region's fishery management bodies.
Starting with SAW-39 (June 2004), the process was revised in two fundamental ways. First, the Stock Assessment Review Committee (SARC) became smaller panel with panelists provided by the Independent System for Peer Review (Center of Independent Experts, CIE). Second, the SARC provides little management advice. Instead, Council and Commission teams (e.g., Plan Development Teams, Monitoring and Technical Committees, Science and Statistical Committee) formulate management advice, after an assessment has been accepted by the SARC. Starting with SAW-45 (June 2007) the SARC chairs were from external agencies, but not from the CIE. Starting with SAW-48 (June 2009), SARC chairs are from the Fishery Management Council's Science and Statistical Committee (SSC), and not from the CIE. Also at this time, some assessment Terms of Reference were revised to provide additional science support to the SSCs, as the SSC's are required to make annual ABC recommendations to the fishery management councils.

Reports that are produced following SAW/SARC meetings include: An *Assessment Summary Report* - a summary of the assessment results in a format useful to managers; an *Assessment Report* – a detailed account of the assessments for each stock; and the SARC panelist reports – a summary of the reviewer's opinions and recommendations as well as individual reports from each panelist. SAW/SARC assessment reports are available online at

http://www.nefsc.noaa.gov/nefsc/publications/series/crdlist.htm. The CIE review reports and assessment reports can be found at *http://www.nefsc.noaa.gov/nefsc/saw/*".
The 56th SARC was convened in Woods Hole at the Northeast Fisheries Science Center, February 19-22, 2013 to review benchmark stock assessments of: Atlantic surfclam and white hake. CIE reviews for SARC56 were based on detailed reports produced by NEFSC Assessment Working Groups. This Introduction contains a brief summary of the SARC comments, a list of SARC panelists, the meeting agenda, and a list of attendees (Tables 1 – 3). Maps of the Atlantic coast of the USA and Canada are also provided (Figures 1 - 5).

Outcome of Stock Assessment Review Meeting:

Text in this section is based on SARC-56 Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC-56 Panelist Reports").

The **Atlantic surfclam** stock is neither overfished nor experiencing overfishing in 2011. The GBK component is nearly in an unfished condition. The surfclam fishery has been concentrated in relatively small areas for economic reasons. Much of the stock area has not been heavily fished. This explains the low overall *F* estimates, and is consistent with previous assessment results. Commercial LPUE trends show striking similarity to the declining surfclam stock trends estimated in the analytical assessment. Therefore, the SARC recommended that a more formal investigation of commercial LPUE for use in the assessment model be undertaken for future assessments. The assumed natural mortality rate (*M* = 0.15) is uncertain and may overstate stock productivity. Further work on M is recommended to better understand stock vulnerability. A statistical catch-at-age and length model (SS3) replaced the biomass dynamic model (KLAMZ) used previously. Stock assessment results from the northern and southern areas were combined to evaluate the status of the stock for the entire EEZ. The SARC could not decide whether to recommend changing from the current single stock definition. The SARC noted that this should not prevent conducting stock assessments by subareas, nor should it preclude area-based management, if appropriate. Although absolute biomass is uncertain, trends in biomass are relatively certain. The ratio B_{2011}/B_{1999}, where B_{1999} is a B_{MSY} proxy, is relatively stable because estimates of B_{2011} and B_{1999} generally vary together. Fishing mortality estimates are less robust because they compare the catch estimate against the less certain scale of biomass. This uncertainty is not considered to be a serious problem in relation to stock status because overall F is estimated to be well below $F_{THRESHOLD}$ = M = 0.15.

The **white hake** stock is not overfished and overfishing is not occurring. This favorable determination of stock status is a change from the previous stock assessment in which white hake was judged to be overfished and subject to overfishing in 2007. Fishing mortality has varied over a wide range since the 1970s but presently is well below the $F_{MSY\ proxy}$. The improving condition of the stock is indicated by the more than three-fold increase in spawning stock biomass from a time series low in 1997. The estimated increase in spawning stock biomass from 2007 to 2011 was during a period when F was low and recruitment was near the long-term average. The 2013 SAW/SARC-56 white hake assessment model was a statistical catch-at-age model (ASAP) incorporating formulations that differed from the 2008 Statistical Catch-at-Age (SCAA) model. Results from the previous SCAA and new ASAP model formulations using revised data were similar in trend and magnitude. The improved stock status is not the result of changing assessment models. Recent recruitment was sampled when carrying out short term projections, while biological reference points (BRPs) were based on recruitment estimates from the entire time series. The SARC-56 Panel did not find a clear reason to derive BRPs based on the shorter, recent time series of recruitment. The SARC-56 Panel recommended that the $F_{MSY\ proxy}$ of F40% currently in place should remain. This decision was based on consideration of the risks of depleting the stock associated with F40% and F35% as well as on the sensitivity of these risks to the assumed stock-recruitment steepness parameter.

SARC-56 concluded the **Atlantic surfclam** and **white hake** assessments were effective in delineating stock status, determining BRPs and proxies, and in projecting probable short-term trends in stock biomass, fishing mortality, and catches.

Table 1. 56th Stock Assessment Review Committee Panel.

SARC Chairman (MAFMC SSC):

Dr. Edward Houde
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SARC Panelists (CIE):

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Table 2. Agenda, 56th Stock Assessment Review Committee Meeting.

February 19-22, 2013

Stephen H. Clark Conference Room – Northeast Fisheries Science Center
Woods Hole, Massachusetts

AGENDA* (version: 15 Feb. 2013)

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR

Tuesday, Feb. 19

10 – 10:30 AM			
Welcome	**James Weinberg**, SAW Chair		
Introduction	**Edward Houde**, SARC Chair		
Agenda			
Conduct of Meeting			
10:30 – 12:30 PM	Assessment Presentation (A. Atlantic Surfclam)		
	Daniel Hennen/Larry Jacobson	TBD	**Toni Chute**
12:30 – 1:30 PM	Lunch		
1:30 – 3:30 PM	Assesssment Presentation (A. Atlantic Surfclam)		
	Larry Jacobson/ TBD (Others)	TBD	**Jon Deroba**
3:30 – 3:45 PM	Break		
3:45 – 4 PM	Public Comments		
4 - 6 PM	SARC Discussion w/ Presenters (A. Atlantic Surfclam)		
	Edward Houde, SARC Chair		**Jon Deroba**

Wednesday, Feb. 20

9 – 10:45 AM	Assessment Presentation (B. White Hake)		
	Katherine Sosebee	TBD	**Kiersten Curti**
10:45 – 11 AM	Break		
11 – 12:30 PM	(cont.) Assessment Presentation (B. White Hake)		
	Katherine Sosebee	TBD	**Kiersten Curti**
12:30 – 1:45 PM	Lunch		
1:45 – 2 PM	Public Comments		

2 – 3:30 PM	SARC Discussion w/presenters (B. White Hake) **Edward Houde,** SARC Chair		**Alicia Miller**
3:30 -3:45 PM	Break		
3:45 – 6 PM	Revisit with presenters (A. Atlantic Surfclam) **Edward Houde**, SARC Chair		**Alicia Miller**
7 PM	**(**Social Gathering – Coonamessett Inn **)**		

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR

Thursday, Feb. 21

8:30 – 10:15	Revisit with presenter (B. White hake) **Edward Houde**, SARC Chair	**Michelle Traver**
10:15 – 10:30	Break	
10:30 – 12:45	Review/edit Assessment Summary Report (B. White hake) **Edward Houde**, SARC Chair	**Michelle Traver**
12:45 – 2 PM	Lunch	
2 – 2:45 PM	(cont.) edit Assessment Summary Report (B. White hake) **Edward Houde**, SARC Chair	**Julie Nieland**
2:45 – 3:00 PM	Break	
3:00 – 6:00 PM	Review/edit Assessment Summary Report (A. Surfclam) **Edward Houde**, SARC Chair	**Julie Nieland**

Friday, Feb. 22

9:00 AM – 5:00 PM SARC Report writing. (closed meeting)

*All times are approximate, and may be changed at the discretion of the SARC chair. The meeting is open to the public, except where noted.

Table 3. 56th SAW/SARC, List of Attendees

Participant Last Name	Participant First Name	Affiliation	Email Address
Adams	Charles	NEFSC	charles.adams@noaa.gov
Alspach	Tom	Sea Watch	talspach@goeaston.net
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Chute	Toni	NEFSC	toni.chute@noaa.gov
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Sosebee	Kathy	NEFSC	katherine.sosebee@noaa.gov

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Wigley	Susan	NEFSC	susan.wigley@noaa.gov
Wood	Tony	NEFSC	anthony.wood@noaa.gov

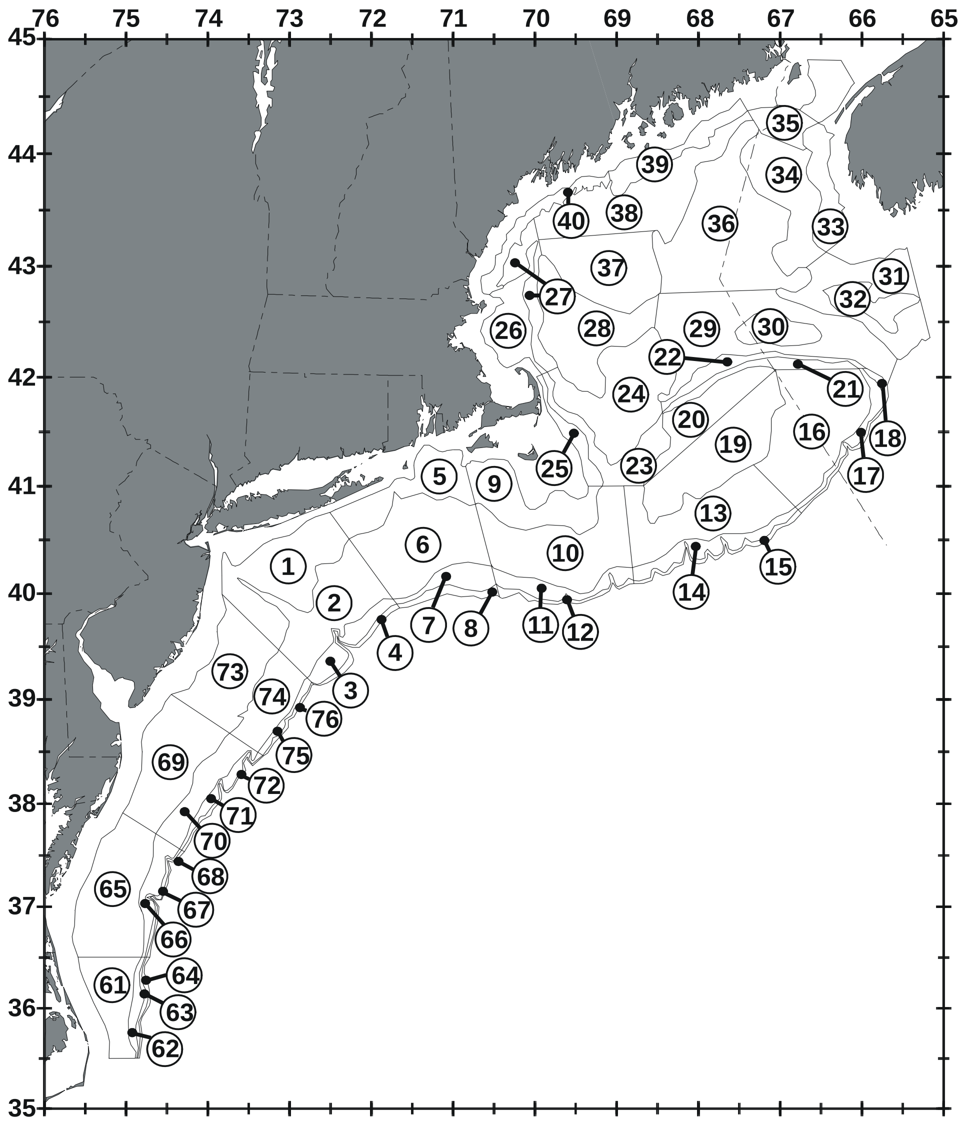

Figure 1. Offshore depth strata that have been sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

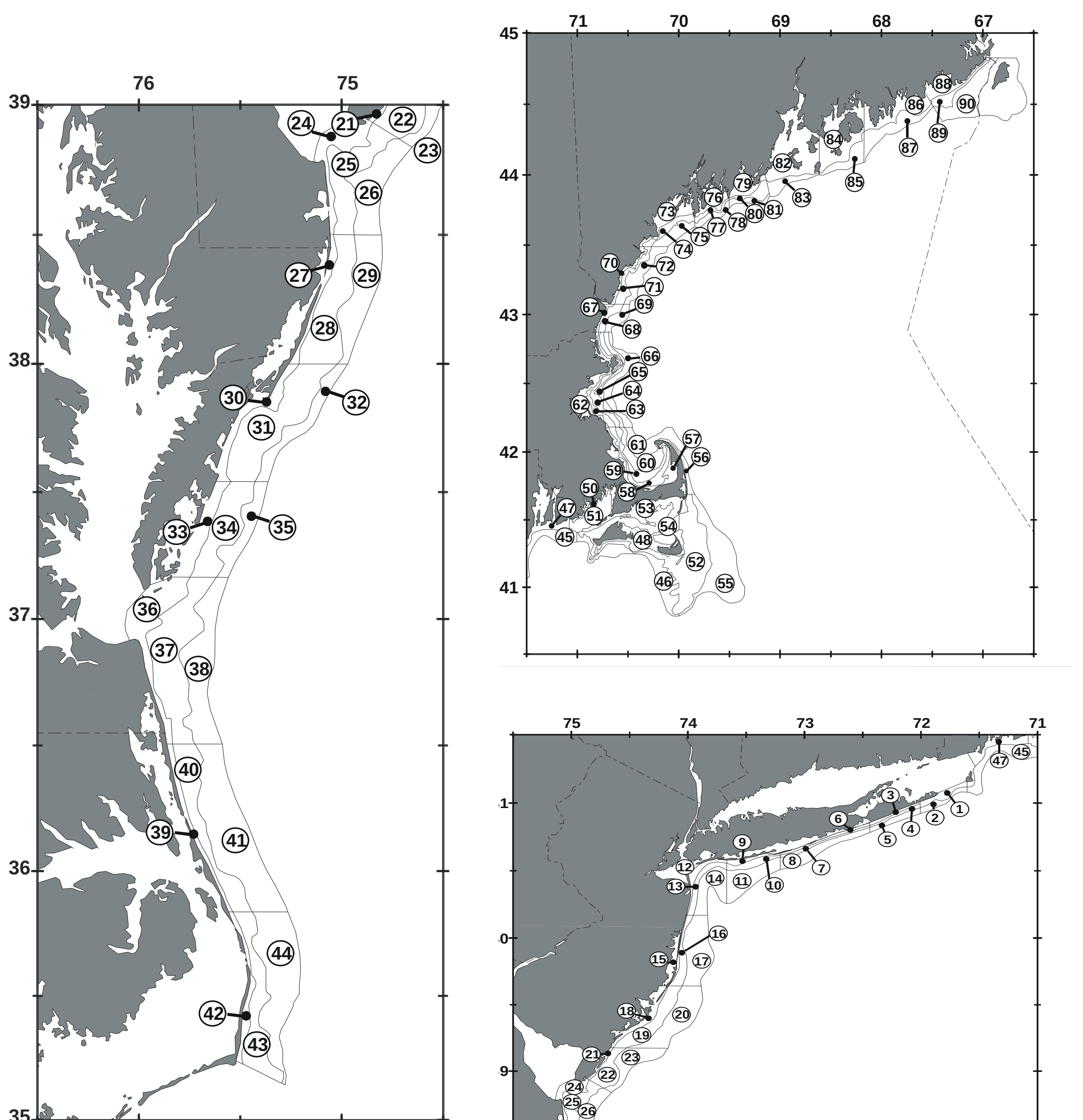

Figure 2. Inshore depth strata that have been sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

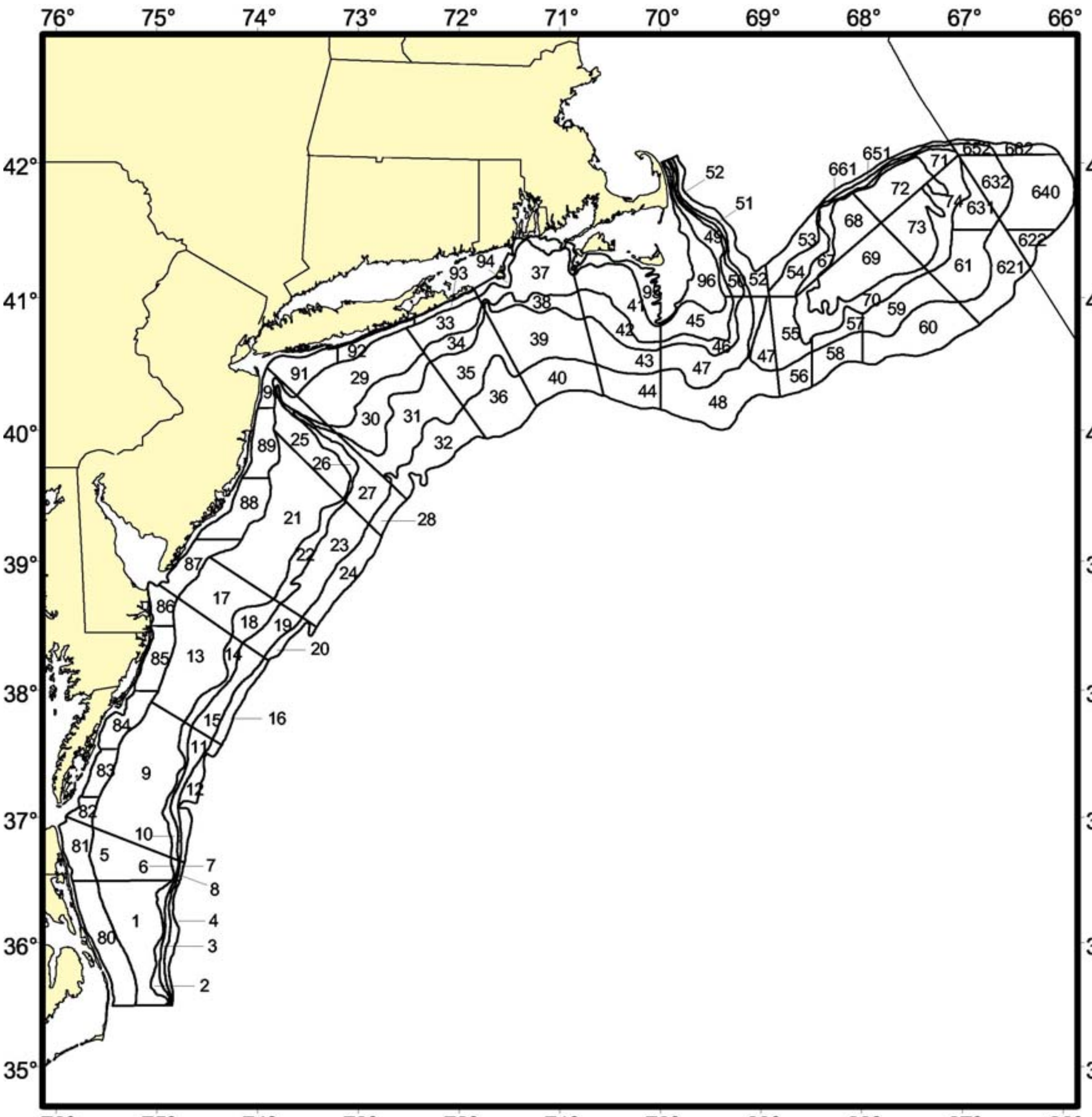

Figure 3. Depth strata sampled during Northeast Fisheries Science Center clam dredge research surveys.

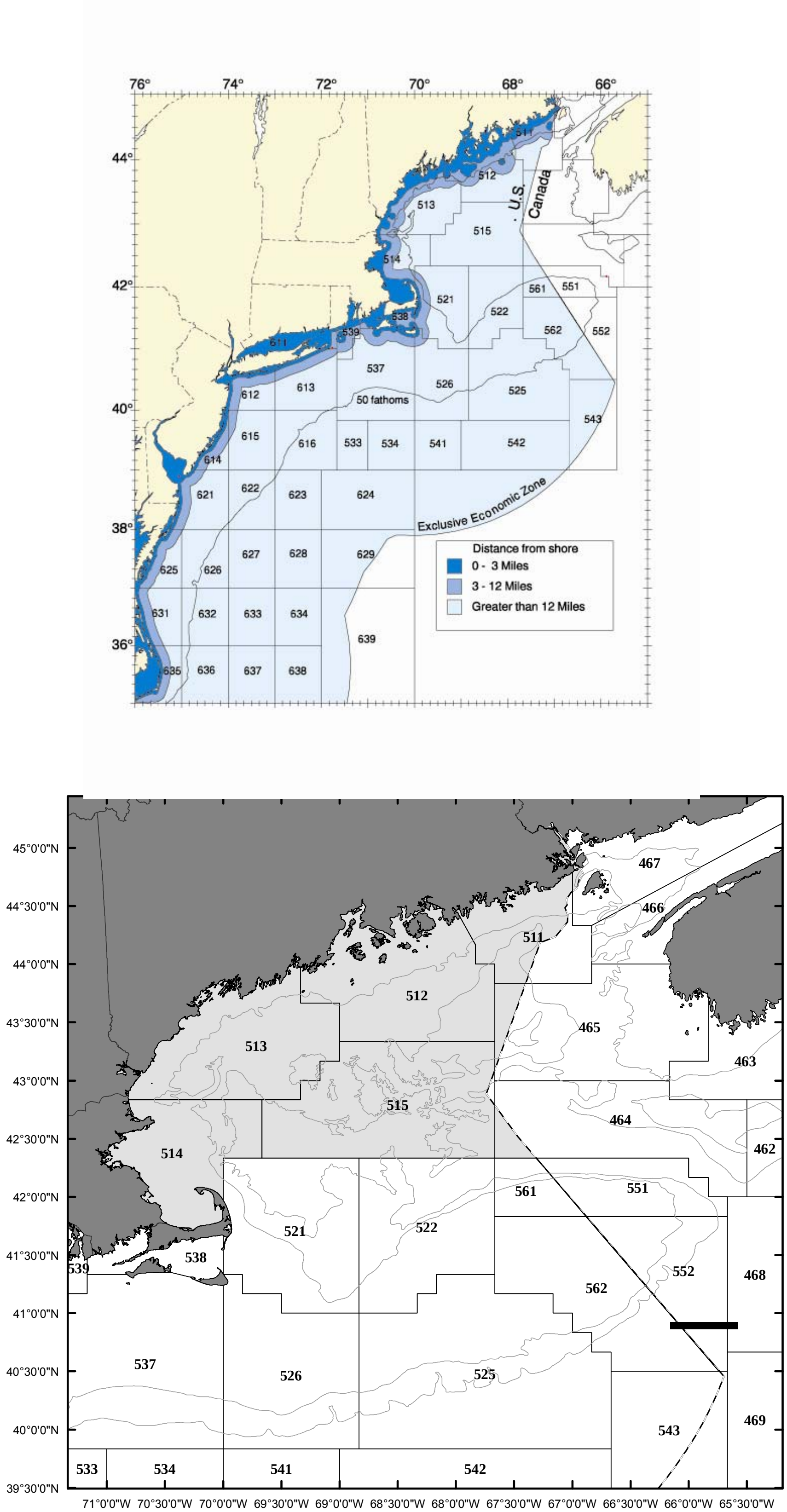

Figure 4. Statistical areas used for reporting commercial catches.

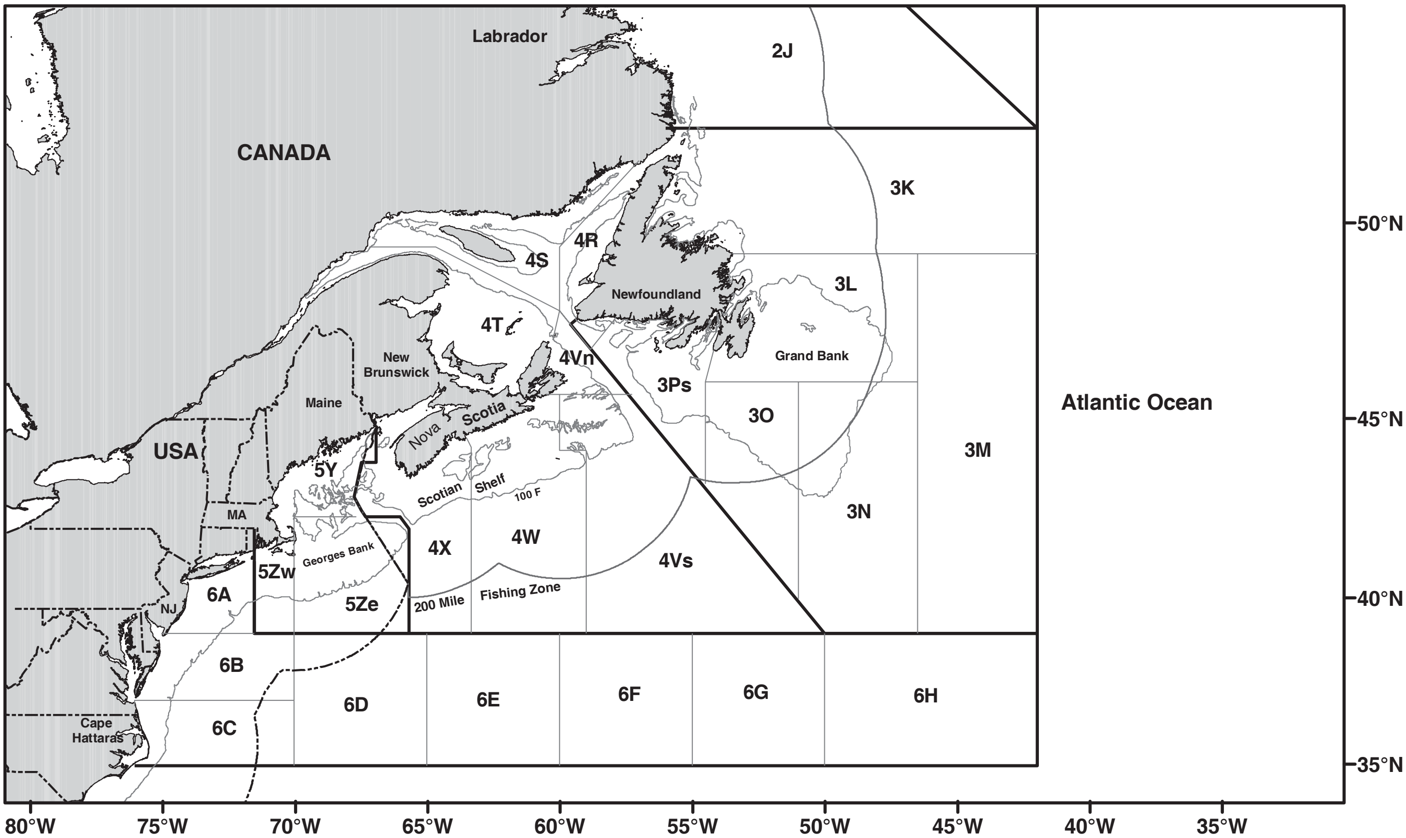

Figure 5. Catch reporting areas of the Northwest Atlantic Fisheries Organization (NAFO) for Subareas 3-6.

A. ATLANTIC SURFCLAM STOCK ASSESSMENT IN THE US EEZ FOR 2013

Terms of reference for Atlantic surfclam

1. Estimate catch from all sources including landings and discards. Describe the spatial and temporal patterns in landings, discards, fishing effort and LPUE. Characterize the uncertainty in these sources of data.

2. Present the survey data being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, relevant cooperative research, etc.). Investigate the utility of commercial LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

3. Evaluate the current stock definition in terms of spatial patterns in biological characteristics, population dynamics, fishery patterns, the new cooperative survey, utility of biological reference points, etc. If appropriate, recommend one or more alternative stock definitions, based on technical grounds. Integrate these results into TOR-4.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-3), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results. Review the performance of historical projections with respect to stock size, recruitment, catch and fishing mortality.

5. State the existing **stock status** *definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. This should be carried out using the existing stock definition and, if possible, for the recommended "alternative" stock definitions from TOR-3. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the appropriateness of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.*

6. Evaluate stock status with respect to the existing assessment model and with respect to any new assessment model. Determine stock status based on the existing stock definition and, if appropriate and if time permits, for "alternative" stock definitions from TOR-3.

a.When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.

b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

7. Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., probability density function) of the OFL (overfishing level) and candidate ABCs (Acceptable Biological Catch; see Appendix to the SAW TORs).

a. Provide numerical annual projections (3-5 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).

b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.

c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

8. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in the most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

Executive Summary

TOR 1. Commercial fishery

About 20,000 mt of surfclam meats (18,600 mt from federal waters) were landed during 2011. Total landings were down slightly from the last assessment (22,519 mt in 2008). Landings during 2011 were mostly from the New Jersey (NJ 64%), Southern New England (SNE 13%) and the Georges Bank (GBK 13%) regions. The Long Island (LI) and Delmarva (DMV) regions supplied about 10% of total landings. About 74% of the total effort in 2011 occurred in NJ, with an additional 15% occurring in SNE. Landings per unit effort (LPUE) were near record low levels, approximately 40 – 60 bushels (bu) per hour except in GBK where they were approximately 290 bu h^{-1}. Commercial surfclam data are considered accurate and precise relative to many fisheries because there is no discarding and few active permits. Landings are reported both in log books and by dealers.

TOR 2. Survey

NEFSC survey data were collected in 2011 aboard the *RV Delaware II*. Recruitment of small surfclams (50 – 119 mm) for the whole EEZ stock has increased since 2005 based on survey data. Survey catch of larger surfclams recruited to the fishery (120+ mm) has been stable since 2005. Despite positive trends, both recruitment and number per tow were below average for the time series. NEFSC, Industry and academic collaborators conducted depletion and selectivity experiments from the *FV Pursuit* in 2011. New estimates of survey dredge efficiency, and selectivity were produced, as well as refinements to shell height to meat weight relationships and growth curve estimates. Age and size composition data from survey catches were used in the primary assessment model for the first time.

TOR 3. Stock definition

The current definition is a single EEZ surfclam stock which extends from Georges Bank (GBK) in the north to Southern Virginia – SVA. An alternative definition would divide the surfclam stock into northern (GBK) and southern (Southern Virginia - SVA to SNE) components. The Invertebrate Subcommittee discussed the technical merits of both approaches but no consensus was reached and conclusions were left to reviewers. The SARC56 Panel concluded the material presented did not contain sufficient information to allow it to reach a decision on stock definition. The SARC Panel noted that this does not prevent the stock assessment from being conducted by subareas, nor does it preclude area-based management. Arguments for and against both options are presented concisely in tabular form with a brief introduction.

TOR 4. Model results

The primary assessment model was a statistical catch at size model, Stock Synthesis (SS3), instead of the biomass dynamic delay difference model (KLAMZ), used previously. Using SS3 allowed the working group to make use of age and size composition data for the first time. Additional changes to the assessment model included: new estimates of capture efficiency, size selectivity, growth curves, shell length to meat weight formulas, and a new approach to modeling the stock, where the GBK and southern areas were modeled separately. Results indicate that biomass was higher and fishing mortality rates that were lower than in previous assessments. In general, population trends appear well estimated while population scale (overall level of biomass in mt) was uncertain.

TOR 5. Stock status definitions

The current overfished threshold for surfclams is ½ B_{MSY} proxy = ¼ B_{1999} and the biomass target is ½ B_{1999}. The overfishing threshold is F=M=0.15. The fishing mortality reference point was considered adequate under either the current or alternative stock definition and no changes were recommended in this assessment.

Biomass reference points depend on which stock definition is adopted. The biomass reference point was considered adequate for the current stock definition and for the southern part of the resource. However, it was not possible to estimate B_{MSY} or a proxy for GBK in the time available because surfclams on GBK have had little exploitation, biomass has changed substantially there in the absence of fishing, environmental conditions are changing and the response of surfclams to fishing could not be predicted. A B_{MSY} proxy for GBK may be an important topic for future research but the question does not affect status determinations in this assessment given that the GBK area is essentially unexploited and cannot, by definition, be overfished.

TOR 6. Stock status

The surfclam population is not overfished and overfishing is not occurring under either the current or alternative stock definitions.

TOR 7. Projections

Projections indicate that the population is unlikely to be overfished and that overfishing is unlikely to occur by 2021 under either, the current or alternative stock definitions and a wide range of assumed catches.

TOR 8. Research recommendations

Research recommendations are discussed.

Introduction

Distribution and biology

Atlantic surfclams are large fast growing bivalves distributed along the coast of North America from the southern Gulf of St. Lawrence to Cape Hatteras (Figure A1), with major concentrations on Georges Bank, the south shore of Long Island, New Jersey and the Delmarva Peninsula. Surfclams are found from the intertidal zone to a depth of 128m but the highest concentrations are found at depths of less than 40m. Off of the Delmarva

Peninsula where the water is warmest, they are distributed in slightly deeper, cooler water. Surfclams, which burrow energetically, inhabit medium-grained sand, although they can also be found in fine or silted sand.

Surfclams are the largest bivalves in the western North Atlantic, reaching a maximum size of about 22 cm (Ropes 1980). Individuals larger than 16 cm shell length (SL - the distance across the longest part of the shell) are relatively common in Northeast Fisheries Science Center (NEFSC) surveys. Growth to commercial size (12 cm) takes about 6-7 years. Weinberg (1998), and Weinberg and Helser (1996), show that growth rates vary among regions, over time, and in response to surfclam density levels. Slower growth in surfclams in DMV and NJ during recent years coincides with mortality in near shore areas probably due to warm water (Weinberg et al 2005)

Surfclams taken in the NEFSC clam surveys are aged regularly. The surfclam shells are sectioned through the chondrophore (the attachment surface for the "hinge" ligament) and the annuli (rings) are counted. Surfclams age 30+ are relatively common and the maximum observed age exceeds 37. Most surfclams have recruited to the fishery (reached a shell length of 12 cm) by the time they are six or seven years old.

Surfclams can reach sexual maturity at three months of age (Cargnelli et al.1999). Sexes are separate, but are not distinguished in either commercial or NEFSC survey data. Spawning is thought to occur from late spring through early fall, generally depending on latitude, with more southern clams spawning earlier. Eggs and sperm are shed directly into the water column. Settlement to the bottom occurs after 19 to 35 days, depending on the temperature. Relationships between age/size, functional maturity and effective fecundity have not been precisely quantified.

There are two subspecies of Atlantic surfclam: The offshore subspecies *Spisula solidissima solidissima,* to which this assessment refers, and the smaller coastal subspecies (*Spisula solidissima similis*) that occupies relatively southern inshore habitats (Weinberg et al 2010). The geographic distributions of the two subspecies overlap to a limited extent in the south and in some inshore waters to the north. However, *S. s. similis* is reproductively isolated from *S. s. solidissima* and not important to the federal commercial fishery. It is likely that all *Spisula solidissima similis* along the northeast coast belong to the same biological population.

See Cargnelli et al. (1999) for a more detailed review of life history and distributional information.

Management

Surfclams are common in both state waters (3 miles or less from shore) and federal waters (the Exclusive Economic Zone - EEZ, between 3 and 200 miles from shore). This stock assessment applies only to the segment of the surfclam population in federal waters because the EEZ is the management unit specified in the Atlantic Surfclam Fishery Management Plan (FMP). Surfclams in New Jersey and New York state waters support valuable fisheries that are managed by state authorities. The state of the inshore portion of the resource is discussed in Appendix A1.

Atlantic surfclams in the US Exclusive Economic Zone (EEZ) are considered a single stock for management purposes, though state and federal stocks are not biologically distinguishable. There are, however, substantial regional differences in biological properties and population dynamics.

Because the surfclam fishery is highly localized and the resource is sedentary, stock conditions are often described for regions, rather than the whole stock area. Names and abbreviations for the stock assessment regions are listed from south to north below (and see Figure A1)

.

Abbreviation	Assessment region
SVA	S. Virginia to N. Carolina
DMV	Delmarva
NJ	New Jersey
LI	Long Island
SNE	Southern New England
GBK	Georges Bank

The southern area consists of the regions from SVA to SNE, excluding only GBK (Figure A2). SVA is at the southern end of the species range and of relatively little importance to the stock as whole.

Georges Bank was closed to surfclam harvesting between 1989 and 2009 due to the presence of paralytic shellfish poisoning (PSP) toxins in surfclam meats. With the recent development of fast, accurate tests for these toxins, fishermen have been able to test catches at sea and determine if they are safe for consumption. Since 2009, limited fishing on GBK has been allowed under an exempted fishing permit for the purposes of testing the PSP safety protocols developed by industry. GBK is open for fishing as of January 1, 2013, contingent on continuous testing and the absence of PSP.

The fisheries for Atlantic surfclams and ocean quahogs (*Arctica islandica*) in the EEZ are unique in being the first US fisheries managed under an individual transferable quota (ITQ) system. ITQ management was established during 1990 by the Mid-Atlantic Fishery Management Council under Amendment 8 to the Fishery Management Plan for the Atlantic Surfclam and Ocean Quahog Fisheries (FMP). Management measures include an annual quota for EEZ waters and mandatory logbooks that describe each fishing trip to a spatial resolution of at least one ten-minute square (TMS, 10' lat. by 10' longitude).

Murawski and Serchuk (1989) and Serchuk and Murawski (1997) provide detailed information about the history and operation of the fishery.

Previous assessments

Stock assessments are generally done after NMFS clam surveys, which are conducted every 2-3 years. Surfclams were previously assessed in 1992, 1994, 1997, 1999, 2003, 2005, and 2008 (NEFSC 1993, 1995, 1998, 2000, 2003, 2007, 2010). The most recent stock assessment for surfclams, NEFSC (2010) concluded that the stock was above the biomass threshold (the stock was not overfished) and that fishing mortality was below the overfishing threshold (overfishing was not occurring). However, biomass was projected to decline gradually through 2014, because recent recruitment had been low and was likely to remain low over the next five years. The uncertainty of these predictions was high due to uncertainty regarding future conditions. A “historical retrospective” analysis in this assessment includes biomass and fishing mortality estimates from previous assessments.

During the NEFSC clam surveys aboard the *R/V Delaware II*, clams were sampled with a 3.2 ton hydraulic dredge, similar to that used by industry but about half the size. A submersible pump, mounted above the dredge, shot water into the sea bottom just ahead of the 1.5m-wide dredge mouth. Commercial dredges have blades 8-12 feet (2.4-3.7m) wide and higher pressure water jets. These jets of water turn the sea bottom into a fluid, which allows the clams to be captured more easily.

Uncertainty in assessment results and the necessity for additional research on abundance were highlighted by NEFSC (1995) because survey catch rates were anomalously high during the 1994 survey in some regions. The anomalously high catch rates were apparently due to a change in voltage supplied to the pump on the survey dredge towed by the *R/V Delaware II*, which increased capture efficiency. Subsequently, a major effort has been made to monitor and improve understanding of the performance of the dredge used in NMFS clam surveys.

Sensors, first deployed in 1997, are used in clam surveys to monitor the performance of the dredge during each tow. Data collected include ship speed and position, dredge angle, voltage and amperage of electrical current that powers the pump on the dredge, manifold pressure (hydraulic pressure just upstream of the nozzles), water depth and water temperature. The sensor data allow for more accurate estimates of distance towed as well as identification of problematic tows. The dredge has been operated in a consistent fashion using the same survey protocols and gear since 1997. In particular, the criteria used to reject bad tows for trend analysis have not changed. Sensor data are used most extensively in analysis of depletion study data to estimate capture efficiency, and in estimation of efficiency corrected swept area biomass.

Cooperative depletion experiments are an important part of surfclam stock assessments. Depletion studies are conducted in collaboration with academia and the clam industry. An industry vessel fishes repetitively to "deplete" a site where the *R/V Delaware II* has already made a small number of non-overlapping tows. As described below, a spatially explicit statistical model (the "Patch" model, Rago et al., 2006) is used to analyze the depletion study data and estimate surfclam density and capture efficiency for the survey and commercial vessels. This assessment includes analysis of data from four new depletion experiments.

This assessment (also described in NEFSC 2013) estimates fishing mortality and stock biomass with efficiency-corrected swept-area biomass calculators, the KLAMZ model, and Stock Synthesis, the main assessment model.

Commercial Catch (TOR-1)

Commercial landings are reported as meat weights in this assessment for ease in comparison to survey data and in calculations, but were originally recorded in units of industry cages. One cage equals 32 industry bushels, and one industry bushel is assumed to produce 17 lbs or 7.711 kg of usable meats. Landings per unit of fishing effort (LPUE) data are reported in this assessment as landings in bushels per hour fished, based on clam logbook reports. The spatial resolution of the clam logbook reports is usually one ten-minute square.

Unit	Equivalent
1 cage	32 bushels
1 bushel	1.88 ft^3
1 bushel	17 lbs meats
1 bushel	7.71 kg meats

As in previous assessments (NEFSC 2010), for all stock assessment analyses "catch" is defined as the sum of landings, plus 12% of landings, plus discards. The 12% figure accounts for potential incidental mortality of clams in the path of the dredge. It is an upper bound; actual incidental mortality is likely to be lower. Incidental mortality to the total surfclam resource is likely low because the total area fished (e.g. 155 km^2 during 2004) is small relative to the spatial area of the resource (Wallace and Hoff, 2005). The ITQ fishery operates with little or no regulation-induced inefficiency (e.g. area closures, trip limits, size limits, etc.) so that fishing effort and incidental mortality are limited.

Recreational catch is near zero, although small numbers of surfclams are taken recreationally in shallow inshore waters for use as bait. Surfclams are not targeted recreationally for human consumption.

<u>Discard data</u>

Discards were zero during 2008-2011 (since the last assessment). Some discards occurred during 1979-1993 (Table A1). No new information about discards was available for this assessment.

<u>Age and size at recruitment to the fishery</u>

Age at recruitment to the surfclam fishery depends on growth rates which vary geographically. Recruitment appears to occur earlier in northern regions. In previous assessments (and in the KLAMZ model discussed in this assessment), commercial selectivity was assumed be knife-edged at 120 mm. Growth curves used in stock assessment modeling (described later) indicate that surfclams reach 120 mm SL and recruit to the fishery at the estimated age of about 6 y south of Georges Bank where most fishing occurs (Figure A2). The age at recruitment depends on the area being modeled (north vs. south), the time period in question, as growth may change over time. Size at recruitment depends on the fishery selectivity estimated in the model. This issue is discussed in detail in the section describing stock assessment modeling (TOR 4).

Landings, fishing effort and prices

Landings and fishing effort data for 1982-2011 were from mandatory logbooks (similar but more detailed than Vessel Trip Reports used in the groundfish fishery) with information on the location, duration and landings of each trip. Data for earlier years were from NEFSC (2003) and MAFMC (2006).

Landings data from surfclam logbooks are considered accurate in comparison to other fisheries because of the ITQ system. However, effort data are not reliable for 1985-1990 due to regulations that restricted the duration of fishing to 6 hours. Effort data are reliable for years before 1985 and after 1990.

Surfclam landings were mostly from the US EEZ during 1965 to 2011 (Table A2 and Figure A3). EEZ landings peaked during 1973-1974 at about 33 thousand mt, and fell dramatically during the late 1970s and early 1980s before stabilizing beginning in about 1985. The ITQ system was implemented in 1990. EEZ landings were relatively stable and varied between 18 and 25 thousand mt during 1985 to 2011. Landings have not reached the quota of 26,218 mt since it was set in 2004 because of limited markets. The quotas themselves are set at levels much lower than might be permitted under the FMP.

The bulk of EEZ landings were from the DMV region during 1979-1980. After 1980, the bulk of landings were from the NJ region (Table A3 and Figure A4). During recent years, EEZ landings from the NJ region have been about 64% of the total, DMV about 8%, and LI and SNE combined about 16%. Landings from LI were modest but appreciable starting in 2001. Landings from SNE were modest but appreciable starting in 2004. Recent LI and SNE landings reflect the tendency of the fishery to move north towards lightly fished areas where catch rates were higher. Landings from GBK were 13% of the total in 2011. Only three vessels were allowed to fish there, and were under the restrictions of an Experimental Fishing Permit. The high proportion of landings on GBK reflects the high catch rates there (see below).

Fishing effort has increased substantially since 1999, particularly in the DMV and NJ regions (Table A4 and Figure A5). The bulk of the fishing effort is in areas where the majority of landings come from. Fishing effort, however, has been increasing in the DMV and NJ regions as the LPUE has declined (see below).

Nominal ex-vessel prices for the inshore and EEZ fisheries have been stable, fluctuating around $9 to $11 per bushel since the mid-1990s (Table A5 and Figure A6). Ex-vessel prices (1991 dollars) decreased steadily in real terms from about $9 per bushel during the mid-1990s to less than $6.50 per bushel during 2008, before stabilizing at approximately $6.80 between 2009 and 2011. Nominal revenues for surfclam during 2011 were about $29 million, making the ITQ surfclam fishery one of the most valuable single species fisheries in the US. In 2011, the ITQ component accounted for 93% of total landings and revenues (Figure A3).

Landings per unit effort (LPUE)

Nominal landings per unit effort (LPUE) based on logbook data was computed as total landings divided by total fishing effort for all vessels and all trips (Table A6. and Figure A7.). Standardized LPUE was not estimated for this assessment because the data are not used analytically and because NEFSC (2007) showed that nominal and standardized trends were almost identical when standardized trends were estimated in separate general linear models for each region with vessel and year effects.

Nominal LPUE has been declining steadily across all regions (except GBK) since 2000. LPUE levels in, NJ, LI and SNE have been at or near record lows, falling to an estimated 41 to 44 bushels per hour in 2011. The only region aside from GBK showing a recent increase in LPUE is DMV which increased from 49 to 60 bushels per hour between 2010 and 2011. LPUE in GBK reached 352 bushels per hour in 2010 and 285 bushels per hour in 2011.

LPUE is not an ideal measure of fishable biomass trends for sessile and patchy stocks like surfclams because fishermen target high density beds and change their operations to maintain relatively high catch rates as stock biomass declines (Hillborn and Walters 1992). However, trends in LPUE and NEFSC clam survey biomass data are highly correlated for DMV and NJ where fishing has been heaviest and fishing grounds are widespread (NEFSC 2010).

Spatial patterns in fishery data

Annual landings, fishing effort and LPUE were calculated by ten-minute square (TMS) from 1979-2011 (Appendix A2) and mean landings, fishing effort and LPUE were calculated by TMS for five time periods: 1980-1990, 1991-1995, 1996-2000, 2001-2005 and 2006-2011 (Figures A8 – A10). Only TMS where more than ten bu of surfclams (estimated by weight) were caught over the time period were included in the maps. TMS with reported landings less than 10 bu were probably in error, or from just a few exploratory tows. Inclusion of TMS, with less than 10 bu distorted the graphical presentations because the area fished appeared unrealistically large.

Figures A8 – A10 show the spatial patterns of the surfclam fishery over the past 32 years. In all the years, the greatest concentration of fishing effort and landings occurred in the same thirty or so TMS in the NJ region, with intermittent fishing activity in other regions. For example, during the first ten-year time period, from 1981 to1990, the highest landings and fishing effort were still concentrated off NJ, but there were some landings and fishing effort mostly offshore in DMV and SVA, and some fishing activity in SNE off of Martha's Vineyard (about 41^{o}N 70^{o}W). During 1996-2000, there were little landings or effort in SVA or SNE, reduced activity in DMV, and increased activity in NJ with expansion to offshore regions. During 2001-2005, fishing effort in DMV increased and fishing effort expanded eastward along the south shore of Long Island. During 2006-2011, some landings came from a small offshore area in DMV, and fishing north of NJ has been mostly limited to the waters adjacent to Long Island and the experimental fishing on GBK.

TMS with the highest LPUE levels over time have been mostly in the NJ and DMV regions with irregular contributions from GBK and the Nantucket Shoals region of SNE. The exception is DMV during 2006-2011, where LPUE is noticeably lower.

Important TMS

TMS "important" to the fishery were identified by choosing the 10 TMS from with the highest mean landings during each of the following time periods 1980-1990, 1991-1995, 1996-2000, 2001-2005 and 2006-2011. For example, a TMS important during 1991-1995 could be selected regardless of its importance during earlier or later time periods. The list contains a total of 28 important TMS, because of overlap between the time periods and because the same TMS tend to remain important. The large majority of important TMS were in the NJ region (18), with 6 in the DMV region, 2 in SNE 1 in GBK. LI and SVA did not qualify in any of the time periods we examined. These plots are complicated by the "rule of three" which states that fine scale fishing location data cannot be shown for areas fished by three or fewer vessels due to confidentiality concerns. Therefore, some otherwise important TMS cannot be depicted here because they were fished by a small number of vessels. Trends in landings, effort and LPUE were plotted (Figures A11 – A13) for each TMS to show changes in conditions over time within individual TMS.

Landings and especially effort have increased recently in one TMS in the DMV region that has historically been lightly fished, but trends show most of the important TMS in the DMV region have seen declining effort and landings over time. Several have not had any reported landings in recent years. Landings and effort have increased in two important TMS in NJ and two in SNE, and appear to be increasing recently (although they are still at low levels) in one of the two NJ TMS that have continuously supported the highest landings in the region for the last 30 years.

With the exception of GBK, there are very few important ten-minute squares in which the LPUE has trended upwards in recent years, if they are still being fished. Most are currently at or below about 100 bushels per hour.

Fishery length composition

Since 1982, port samplers have routinely collected shell length measurements from ~30 random landed surfclams from selected fishing trips each year (Table A7.). During 1982-1986, length data were collected from over 5,000 clams in each of the DMV and NJ regions, where most surfclams are landed. Since 1986 an average of about 1000 lengths from DMV and 1500 from NJ have been collected each year. Surfclams were measured from SNE landings every year from 1982 to 1990, although in small numbers with a maximum of 810 in 1988. Samplers began collecting from SNE once again in 2010 and collected over 2000 lengths in 2011. Port samplers began taking measurements from landings from the LI region in 2003 and have been collecting them consistently ever since, but only about 400 lengths are measured per year on average.

Port sample length frequency data from the four regions show modest variation in size of landed surfclams over time (Figures A14 – A18). Surfclams from the SNE region are larger than surfclams from more southern areas. Care should be taken in interpreting these due to small sample sizes in some cases (especially LI and SNE), but in general the data indicate that most landed surfclams have been larger than 120mm SL, with the distribution of sizes being wider some years than others on both ends of the distribution. Commercial size distributions are discussed in detail in the SS3 model section (see below).

NEFSC and Cooperative clam surveys (TOR-2)

Survey data used in this assessment were from NEFSC clam surveys conducted during 1982-2011 by the *R/V Delaware II* during summer (June-July), using a standard NEFSC survey hydraulic dredge with a submersible pump. The survey dredge had a 152 cm (60 in) blade and 5.08 cm (2 in) mesh liner to retain small individuals of the two target species (surfclams and ocean quahogs). The survey dredge differed from commercial dredges because it was smaller (5 ft instead of 8-12.5 ft blade), had the small mesh liner, and because the pump was mounted on the dredge instead of the deck of the vessel. The survey dredge was useful for surfclams as small as 50 mm SL (size selectivity described below). Changes in ship construction, winch design, winch speed and pump voltage that may have affected survey dredge efficiency were summarized in Table A7 of NEFSC (2004). Each of these factors has been constant since the 2002 survey.

Surveys prior to 1982 were not used in this assessment because they were carried out during different seasons, used other sampling equipment or, in the case of 1981, have not been integrated into the clam survey database (Table A7 in NEFSC 2004).

NEFSC clam surveys are organized around NEFSC shellfish strata and stock assessment regions (Figure A1). Most surfclam landings originate from areas covered by the survey. The survey did not cover Georges Bank (GBK) during 2005 and provided marginal coverage in 1982, 1983, and 1984. Individual strata in other areas were sometimes missed. Strata and regions not sampled during a particular survey were “filled” for assessment purposes by borrowing data from the same stratum in the previous and/or next survey, if these data were available (Table A8.). Survey data were never borrowed from surveys behind the previous, or beyond the next survey. Despite research recommendations, a model based approach to filling survey holes has not yet been adopted. A model-based imputation was investigated for this assessment, but the imputation tended to over-emphasize unsampled years and areas. Alternative approaches to imputing missing strata remain a possibility but were not further pursued in this assessment.

Surveys follow a stratified random sampling design, allocating a pre-determined number of tows to each stratum. A standard tow is nominally 0.125 nm (232 m) in length (i.e. 5 minutes long at a speed of 1.5 knots) although sensor data used on surveys since 1997 show that tow distance increases with depth, varies between surveys and is typically longer than 0.125 nm (Weinberg et al., 2002). For trend analysis, changes in tow distance with depth were ignored and survey catches were adjusted to a standard tow distance of 1.5 nm based on ship's speed and tow start/ stop times recorded on the bridge.

Stations used to measure trends in surfclam abundance were either random or "nearly" random. The few nearly random tows were added in some previous surveys in a quasi-random fashion to ensure that important areas were sampled. This generally occurred when stake holders or the assessment lead wished to increase sampling intensity in a stratum of particular interest. Stations added this way were different from other random stations in that they deviated from the pre-determined sampling design described above. They were otherwise random with respect to location within a stratum and thus are called "quasi random". Other non-random stations are occupied for a variety of purposes (e.g. depletion experiments) but not used to estimate trends in abundance.

Occasionally, randomly selected stations are too rocky or rough to tow through, particularly on GBK. Beginning in 1999, these cases trigger a search for fishable ground in the vicinity (0.5 nm) of the original station (NEFSC 2004). If no fishable ground is located, the station is given a special code (SHG=151) and the research vessel moves on to the next station. The proportion of random stations that cannot be fished is considered an estimate of the proportion of habitat in a stratum or region that is not suitable habitat for surfclams. These estimates are used in the calculation of surfclam swept-area biomass (see below).

Following almost all survey tows, all Atlantic surfclams in the survey dredge were counted and shell length was measured to the nearest mm. A few very large catches were subsampled. Mean meat weight (kg) per tow was computed with shell length-meat weight (SLMW) equations (updated in this assessment) based on fresh meat weight samples obtained during the 1997-2011 surveys (see below).

Locations and catches of all stations in the 2011 survey have been mapped (Figure A19.) and maps for previous surveys can be found in Appendix A3.

Survey tow distance and gear performance based on sensor data

There are some applications where it is desirable to know the tow distance with more certainty than is provided using the nominal tow distance. Beginning with the 1997 survey, sensors were used to monitor depth (ambient pressure), differential pressure (the difference in pressure between the interior of the pump manifold and the ambient environment at fishing depth), voltage, frequency (hertz) and amperage of power supplied to the dredge, x-tilt (port- starboard angle, or roll), y-tilt (fore-aft angle, or pitch) and ambient temperature during survey fishing operations. At the same time, sensors on board the ship monitor electrical frequency, GPS position, vessel bearing and vessel speed. Most of the sensor data are averaged and recorded at 1 second intervals. These metrics of tow performance can be used to accurately gauge the true distance fished by the dredge.

Analysis of sensor data from the 2011 NEFSC survey

The survey sensor package (SSP) was deployed on the NEFSC clam survey dredge during the 2011 survey. The SSP provided differential pressure measurements on 187 out of 430 total tows. On other tows (generally between tows 161 and 371) the SSP did not function properly. Back up sensors (Vemco Minilog depth/temperature recorders) failed to produce useful information due a gradual calibration drift that overlapped the period during which no SSP data was recorded. Because the shift in baseline pressure was systematic and began at an unknown point, no data from the Minilog recorders was used. Electric current supplied to the pump on the survey dredge was successfully logged for every tow (Figure A20).

A predictive relationship exists between the electric current supplied to the dredge and the differential pressure in the dredge pump manifold (Figure A21). This relationship was explored in the previous assessment (NEFSC 2009). The previous assessment provided a tolerance point for minimum differential pressure of 35 PSI based on analysis of dredge operation (NEFSC 2009). The current approach maintains that minimum tolerance but does not use the previous upper bound for differential pressure (40 PSI), because pump pressure was generally higher in 2011 (Figure A22).

The parameters estimated in 2009 do not provide a good fit to the data from the 2011 survey. It is likely that the operating specifications have changed somewhat due to alterations in procedure and equipment. For example, the dredge pump was rebuilt and the electrical supply line was replaced after the 2009 survey. These pieces of equipment will have slightly different properties from those used in 2009, and thus produce a subtly different relationship between current and differential pressure.

We compared four different models for predicting differential pressure from current supplied to the pump. We used only current measured while the dredge was fishing (fishing seconds - see below). Current was the smoothed mean (7 second moving average) of three different amperage meters on the research vessel. Our models were fit to the smoothed (7 second moving average) differential pressure recorded by the SSP for the 187 tows where it functioned (Figure A21). The models tested were: a simple power function (M1), the model fit to the data from 2009 (M2), a cubic spline (M3) and a Loess spline (M4, Figure A23). Model selection was based on the models ability to correctly distinguish the tows with SSP data in which differential pressure that was above or below tolerance (35 PSI). Predicted differential pressure was plotted against observed values. Where predicted and observed values were together above or below the tolerance line, the model was considered to have segregated correctly. When the predicted and observed values did not agree on whether or not the differential pressure was above 35 PSI, the model failed to segregate correctly. The cubic spline model produced the highest percentage of correctly segregated points (Figure A24).

The cubic spline fit was then used to predict the differential pressure for all tows, including those for which we measured differential pressure. If the model predicted differential pressure was below 35 PSI for more than 25% of the fishing seconds that tow was considered a "bad" and not used in this assessment for calculating swept area abundance or biomass from surveys since 1997 (Table A9). These tows were, however, used in conventional trend analysis, unless there was an obvious problem noted by the survey crew, because historical surveys did not have sensors.

Determination of time fishing

The determination of time fishing, the "fishing seconds" for each tow was based on a measurement of the pitch of the dredge during each second of the tow. Pitch was recorded by two different instruments: the SSP, which functioned intermittently, and a Star Oddi inclinometer which functioned consistently. Data from each instrument was smoothed using a 7 second moving average and then parsed for time below the "critical angle".

The choice of critical angle has implications for the calculation of tow distance for each tow. When the dredge is above the critical angle it is assumed to be pitched too steeply for the blade to penetrate the sediment. If the dredge is pitched below the critical angle, it assumed to be near enough to horizontal that the blade should penetrate and thus be actively fishing.

An ideal critical angle is as close to zero as possible. When the dredge is bouncing over rough terrain it is unlikely to be fishing effectively and those seconds should be excluded. There is however, a certain amount of pitch that is within fishing tolerance and a certain amount of noise in the data. If the critical angle is too small, many seconds when the dredge was actually fishing would be excluded, which would tend to bias estimates of tow distance down. It is therefore important to find a critical angle for tow distance that is neither too small, nor too large.

The critical angle in the last assessment was 5.16 degrees, a value chosen because it represents a blade penetration of 1 inch (in.) on level ground. Our examination of the sensor data from 2011 provided no compelling reason to use a different critical angle (Figure A25). That is, shifting the critical angle upwards produced only slightly longer tows on average and this shift was not sufficient to trigger a reconsideration of the mechanically derived, blade penetration based estimate, used previously. Therefore the critical angle used in the current assessment was also 5.16 degrees.

NEFSC clam survey trends and size composition

NEFSC clam survey data (Table A10.) were tabulated for small (50-119 mm SL, Figure A26.) and large (120+ mm SL, Figure A27) surfclams by year, region and for the entire stock. Only trends in mean numbers per tow were plotted because trends in mean kg per tow were similar. Approximate asymmetric 95% confidence intervals were based on the CV for stratified means and assume that the means were log normally distributed.

Survey trends for small surfclams (Figure A26.) show low recruitment levels during recent years in the Delmarva (DMV) and New Jersey (NJ) regions, approximately average recent recruitment levels in Southern Virginia (SVA), and Southern New England (SNE), high recruitment levels in Long Island (LI) and low recruitment in GBK. Recruitment appears to be increasing in SVA, LI, and possibly DMV. Survey trends for fishable (120+mm) surfclams (Figure A27.) show low abundance in the SVA, DMV and NJ region during recent years. In comparison, the other regions are either increasing (GBK and possibly LI) or variable (SNE). Based on survey data for the entire stock, recruitment was increasing, but fishable abundance was slightly below average during 2011 (Figures A28 – A29).

Shell length composition data (Figure A30.) are compatible with patterns in trend data. In particular, abundance and recruitment appear low in the southern DMV and NJ regions while abundance is higher and recruitment is at near average levels in the northern LI, SNE and GBK regions.

NEFSC survey age composition

Surfclam ages are considered to be reliable and the aging process has been studied in detail (See Appendix A4 NEFSC 2009; Jacobson et al 2006; and http://www.nefsc.noaa.gov/fbp/QA-QC/data/surfclam/).

In this assessment, "recognizable" recruitment events are year classes that are strong enough to be detected by visual examination. "Strong" recruitment events are year classes that are obviously large relative to other years.

Survey age-length keys and stratified mean length composition data were used to estimate the age composition of surfclams in NEFSC clam survey catches and the stock as a whole by year and region. Age composition was estimated for the years between 1982 and 2011when surveys occurred. Ages ranged from 1-37 (Figures A31 – A36). Specific year classes and trends in age composition are discussed in the context of the assessment model (see TOR 4).

Dredge efficiency

Estimation of dredge efficiency is based primarily on the results of depletion experiments conducted with industry and academic collaborators aboard commercial vessels (NEFSC 2009). In 2011 additional depletion experiments were carried out aboard the *FV Pursuit* (see below). Procedures for estimating dredge efficiencies were modified considerably for this assessment based on Hennen et al (2011) and the incorporation of previously unrecognized uncertainty.

Dredge position during depletion experiments was approximated by vessel position, which was measured via GPS every one second. The true start and stop times for a tow were determined using a Star Oddi inclinometer mounted on the dredge which recorded the angle of the dredge every 1 second. The inclinometer data were smoothed with a 7 second moving average. The dredge was assumed to be fishing when the smoothed dredge angle was less than a_{crit} degrees and the dredge was assumed not fishing when the smoothed inclinometer subsequently increased to an angle greater than a_{crit} degrees. The value a_{crit} was determined by testing critical angles between 2 and 12 degrees and comparing the total tow distance and average tow distance across all depletion experiments (Figure A37). There was an asymptote at angles greater than 8 degrees. That is, total tow distance and average tow distance did not change appreciably with any critical angle between 8 and 12 degrees. We selected 10 degrees as a critical angle. The time stamps for the true start and stop times were used to determine the vessel position during the tow. These data were smoothed with a loess spline (span =0.75, degree = 2) to both longitude and latitude. The choice of smoothing algorithm did not make appreciable differences in the total tow distance across depletion experiments or in the average distance per tow within an experiment (Figure A38). The smoothed vessel positions were used in the patch model to determine tow paths.

The previous assessment (NEFSC 2009) used an estimator for survey dredge capture efficiency that was based on the ratio of observed density in the “set up tows” with the density estimate derived from depletion experiments conducted at the same site. Set up tows were conducted aboard the *RV Delaware II* using the survey dredge described above. They were 5 parallel tows evenly spaced over 1 km at the sites selected for depletion experiments. The set up tows were oriented perpendicularly to the expected direction of depletion tows. The estimator was:

$$e = \frac{d}{D}$$

where *e* is estimated survey efficiency, *d* is the observed density in setup tows and *D* is the estimated depletion experiment density. The implicit assumption of this analysis is that *d* and *D* are estimating the same true density. The estimated survey efficiency used for several calculations in this assessment was the median of all the usable depletion experiments (NEFSC 2009).

Survey dredge efficiency has been difficult to estimate with reasonable precision. It is likely that dredge efficiency is affected by local conditions such as substrate properties, currents and wind. It may be highly variable from site to site. We found that although the quantity *d* was reasonably stable from site to site it carried a high variance (Figure A39.) relative to the quantity *D*. This variance was ignored in previous assessments. Uncertainty in d was carried into the estimate of *e* in this assessment.

We considered a suite of independent variables that might provide additional information about *e*. In 2008, a series of repeat tows were conducted using survey gear in the same location towed previously by the NMFS survey (NEFSC 2009). These "repeat stations" thus provide information about the ability of the survey gear to capture clams when compared to commercial gear. The commercial gear has relatively well understood selectivity. The density observed in the commercial gear was scaled to approximate true density, using its estimated selectivity curve $D_L = \frac{D_{L(obs)}}{Slx_L}$. Thus the observed catch in the survey dredge divided by the rescaled catch in the commercial dredge provided a second measure of survey dredge efficiency.

The selectivity stations (described below) were also a potential source of information on survey dredge efficiency. At selectivity stations, the observed survey density was compared to the rescaled (see above) commercial catch at the same site.

The data from these three sources were truncated. All values larger than 1.0 were discarded due to implausibility (catch in the survey dredge must be less than or equal to the total number of available clams). All sites where 0 clams were caught were not used based on the assumption that if clams were available, the gear would catch at least one of them during a 5 minute tow.

The resulting estimates of survey dredge efficiency from all of these sources of information together provide the set of prior knowledge on survey dredge efficiency (Figure A40.). Each individual estimate has an associated CV. For the depletion sites the CV was estimated directly from the numerical estimation procedure used to fit the Patch model. For the repeat and selectivity sites the CV was based on the pure error variance derived from the set of combined estimates. These values were bootstrapped 100000 times using a weighted bootstrap procedure in which the weights were proportional to the inverse CV associated with each estimate. A bounded (0,1) log normal prior distribution was fit to the bootstrapped data set (Figure A41.). The mean and CV of the log normal distribution were 0.234 and 1.32, respectively. The log normal distribution described by these parameters was the prior distribution for survey *q* used in the assessment models. The mean is similar to the estimate of survey dredge efficiency used in the last assessment (0.256), though the CV is considerably larger when compared to the previous value (0.13).

New Depletion Experiments

The 2011 depletion experiments were analyzed using standard Patch methodology with one exception. We employed a new method for calculating the hit matrix (Hennen et al, 2011). Three of the four SC depletion experiments worked well. Estimated densities ranged from 0.184 – 0.416 clams per m^2 (Table A11). Estimated efficiencies ranged from 0.556 – 0.738. These values are similar to values from previous assessments.

Maps of the tow sequences from the depletion plots show thorough coverage of study sites with high degrees of overlap between tows, which follows procedures recommended by (Hennen et al, 2011) (Figure A42). Recommended patch model diagnostics include examining the catch vs. expected catch, the catch per unit of effective area and the likelihood residuals (Figure A43-A46). We generated likelihood profiles for each of the three estimated parameters for each experiment (Figure A47-A49). The confidence intervals shown in Table 1 are based on the likelihood profiles.

The one depletion study that did not produce reasonable estimates (SC11-04) suffered from a very low catch in the 13^{th} tow of the depletion sequence. Altering this value toward the expected catch changes the Patch model results to estimated values that closely agree with results from the other three SC depletion experiments. We examined all the available logs for tow 13 and found no errors. Inclinometer and pressure sensors did not indicate any mechanical problems during this tow and the tow was of normal length. In short there was no *a priori* reason to exclude this tow from the depletion sequence.

Size selectivity

Survey dredge selectivity was previously calculated using Millar's (1992) SELECT model and precision was estimated using Miller's beta-binomial model (NEFSC 2009). Selectivity was estimated for this assessment using a generalized linear mixed model (Pinheiro and Bates 2000). The data were collected by the *R/V Delaware II* and *F/V Pursuit* during cooperative selectivity experiments in 2008 and 2011. Data from the experiments were used to estimate size-selectivity for the NEFSC clam survey dredge which is used on the *R/V Delaware II*. The data were also used to estimate size selectivity for the commercial dredge used by the *F/V Pursuit* when repeating NEFSC 2008 and 2011 clam survey stations. The commercial dredge was configured for survey operations, rather than commercial fishing operations. Thus, the size selectivity estimates for the commercial dredge used by the *F/V Pursuit* during cooperative survey work are not applicable to commercial catch data.

They may be useful, however, in anticipating the size selectivity of commercial dredges configured for use in cooperative surveys.

As described below, the size selectivity experiments analyzed for this assessment had a paired-tow design, because the tows were conducted in the same general area. R/V and F/V stations more than 300 m apart based on GPS position data were not used.

The data available for each selectivity study site included shell length data from: one R/V tow; one F/V repeat tow with the modified commercial dredge; and one F/V selectivity tow with a commercial dredge lined with wire mesh.

The *F/V Pursuit* has two dredges, each 12.5 feet (3.8 m) wide, which are towed separately. The knives on both dredges were set at 5.25 inches (13.3 cm) for surfclam cooperative survey operations. The starboard dredge used for F/V selectivity tows was lined with 1-inch (2.54 cm) hexagonal wire mesh to maximize retention of small surfclams.

After F/V repeat tows, the catch was dumped into the port or starboard hoppers and then moved mechanically onto a larger, centralized belt to a shaker table and then onto a sorting belt where sampling occurred following F/V repeat tows. The large belt before the shaker table was about 4 feet (1.2 m) wide and 10 feet (3 m) long. Alongside the belt was a large metal stand where the catch could be sampled before it reached the shaker table where mechanical sorting occurred. The average spacing between the rolling bars on the shaker table was 0.73 (+/- 0.10) inches which was narrower than during normal commercial operations.

Surfclams were measured to the nearest mm. F/V repeat tows used the port (unlined) commercial dredge. R/V and F/V repeat tows were 5-minutes in duration. F/V repeat tow catches were allowed to run over the shaker table and onto the sorting belt in the normal fashion before sampling, to measure the effects of both the dredge and shaker table on shell length data. The entire catch was measured following R/V tows following standard survey protocols. The number of bushels was counted for F/V tows and a subsample of three full bushels was measured.

For F/V selectivity tows, the lined dredge was towed for 45 seconds along a track adjacent to the F/V repeat tow. The catch was sorted before going over the shaker table to avoid loss of small surfclams due to mechanical sorting on deck. All clams in three full bushel samples were measured to the nearest mm. Inclinometer data used elsewhere to measure area swept were not available for F/V selectivity tows with the lined dredge. Positions were measured at the start and stop of each selectivity tow by GPS.

Shell length data from selectivity experiments were tabulated using 1 mm shell length size groups. Survey size selectivity was estimated using data from R/V (survey and repeat) tows and FV selectivity data from 40 total sites (10 mm bin summaries in Table A12 – A13).

Previous selectivity estimates

In the last assessment, the Invertebrate Subcommittee decided that the dome shaped curve was the best estimate of size selectivity for the NEFSC survey dredge (NEFSC 2009). Beta-binomial confidence intervals suggested that the domed shaped pattern was real although most of the evidence was based on only two SL groups (160 and 170 mm SL).

The dome shaped size selectivity curve seems biologically plausible. Large surfclams (150+ mm SL) have long siphons and live deeper in the sediments. They may be difficult to dislodge using the light survey dredge with relatively low pressure at the nozzles (about 40 psi compared to about 80 - 120 psi on a commercial dredge).

The selectivity experiments conducted in 2011 were designed to address questions about the appropriateness of a domed shape selectivity curve.

Current selectivity estimates

All R/V and F/V data were combined so that there was a single set of R/V, F/V repeat and F/V selectivity data (Table A12.; Figure A50.).

Selectivity was modeled as a generalized additive model (GAM) where the shell length bin was a factor, predicting the binomial proportion of the survey catch over the total catch (R/V + F/V).

$$p_L = e^{a+s(L)+s(sta)+offset(s.a.ratio)}$$

Where p_L is the binomial proportion (logit link) estimated for shell length L with intercept α and vector of model terms evaluated over L. The *s()* terms indicate a spline over the indicated variables, in this case shell length (L) and a random effect due to station and year. The final term is an offset (MacCullagh and Nelder, 1989) based on the ratio of swept areas between the respective tows at each station. For example, at station 7 the lined dredge swept 242.4 m^2 while the research dredge was towed 318.2 m^2 (Figure A51). Area swept by each gear is a potential source of bias because clams can be unevenly distributed on the sea floor. The nominal time fished for the lined dredge is 45 s compared to 5 min. for a nominal survey tow. The commercial dredge however, is much larger and is towed at a faster speed, which tends to minimize the differences between the gears in area swept.

Using the GAM methodology allowed greater flexibility in the model, when compared to assuming any particular shape. The basis dimension (k) in a spline determines the amount of "wiggle" allowed in the spline. Wood (2009)**1** suggests an objective method for choosing a basis dimension in splines. This method allows the data to determine the shape required to adequately fit them rather than the modeler.

The last assessment assumed a double logistic shape when modeling selectivity (though the fit from the double logistic was contrasted with a logistic fit, which allowed for a comparison of at least two shape families in the model selection process). The double logistic shape is described by a monotonic increase to a peak value, and a subsequent horizontal surface, followed by a monotonic decrease. The current approach estimates a spline along the range shell lengths and thus the peak may occur at any point and multimodal shapes are allowed.

The inclusion of random effects based on station is important because there is a great deal of variation in selectivity between stations. Variation across stations is essentially a nuisance parameter in our assessment because we are interested in the general selectivity over all possible stations, rather than the differences between them. Because we believe that clams taken from a particular place and time would tend to experience similar selectivity when compared to clams taken from a different place and time, it is appropriate to model selectivity using random effects.

Approximate confidence intervals were estimated using

$$CI_L = elogit(\rho_L \pm 1.96 * \sigma_L)$$

1 See R package mgcv documentation: http://127.0.0.1:19246/library/mgcv/html/choose.k.html

Where CI_L is the approximate confidence interval for length L, ρ_L is the corresponding selectivity estimate, σ_L is its standard error and *elogit* is the inverse of the logit function.

It is clear from the model results (Figure A52) that the domed selectivity curve estimated in the last assessment is appropriate. It is also clear that the domed shape is present in most of stations we sampled (Figure A53.). That is, the dome shape is not driven by data from a single site.

The ρ_L estimates were rescaled in some applications so that the highest value was fully selected, that is, equal to 1.0 (Figure A54.). This was necessary because selectivity may be used in product with gear capture efficiency which is defined as the probability of capture (between zero and one) for an organism fully selected by the sampling gear.

Rescaled selectivity was applied to the survey data using the inverse estimated ρ_L as a multiplier for the aggregate animals of each size on each tow. That is, if n_L animals in size class L were caught on a survey tow, we multiplied n_L by $1/\rho_L$, thus n_L/ρ_L rather than n was used to compute the stratified means for the survey index used in the KLAMZ assessment models. The SS3 models estimated selectivity internally and this adjustment to the survey data was not made.

Fishery selectivity

Fishery selectivity experiments were conducted on the F/V Pursuit. A modified fishery dredge (described above) was towed for five minutes as part of the selectivity sequence. The catch by size from this tow was compared to the lined dredge catch at each site. The selectivity estimates for each size class were found using models similar to the ones described above. Data from 2008 was combined with data from 2011. The same model (eq. 1) with offsets based on swept area ratios (Figure A55.) was preferred by AIC. Rescaled fishery selectivity estimates were useful for comparison to internally estimated commercial selectivity from SS3 (Figure A54.).

Shell length, meat weight relationships

The shell length-meat weight (SLMT) relationships are important because they are used to convert numbers of surfclams in survey catches to meat weight equivalents. The survey meat weight equivalents are inputs in the stock assessment models used to estimate stock biomass, which is reported in units of meat weight.

Meat weights for surfclam include all of the soft tissues within the shell. All meat weights greater than 0.5 kg were assumed to be data entry error, and were removed from the analysis.

Generalized linear mixed models (GLMM; Venables & Dichmont 2004) were used to predict clam meat weight, using equations of the form:

$$MW = e^{a+b_0 ln(L)+b_1 ln(c_1)+b_2 ln(c_2)+\cdots+b_n ln(c_n)}$$

where *MW* was meat weight, *L* was shell length, $c_1,\ldots,c_n$ were covariate predictors (e.g., region; in the basic model these are absent), and *a* and the b_i were parameters to be estimated. Examination of the variance of the weights as a function of shell length indicated that weight increased approximately linearly with shell height, implying that the Poisson family was appropriate for the distributions of meat weights (McCullagh & Nelder 1989). The GLMMs in all analyses therefore used the Poisson family with a log link. Because shell length/weight relationships for clams at the same station are likely to be more similar than those at other stations, we considered the sampling station as a grouping factor ("random effect") in the analysis.

We fit models with fixed effects for year and region (Table A14.). Neither of these factors proved to be important using AIC (Table A14). The best model by AIC and BIC was a model with fixed effects for shell length and depth and random effects for shell length slope and the intercept, using both the year and the station as the grouping variables.

$$E(MW) = exp\big(\alpha(1 + r_{sta}) + \beta(lnL + r_{sta}) + \gamma lnD + \delta_{Reg} + \epsilon_{Yr}\big)$$

where $E(MW)$ is the expected meat weight (in g) and r_{sta} is the grouping variable for the random effects (station). The important predictors of meat weight are: ln(length), ln(depth), region and year.

Random effects improved the model fit (i.e., decreased the AIC, Table A14.) in all analyses, demonstrating that individuals at the same sampling site are more similar to each other than to the general population. When multiple samples are collected at each site and random effects are not accounted for, the results typically overstate the precision of parameter estimates. This occurs because the analysis assumes that within-site observations are independent when, in fact, they often are highly correlated.

The GLMM approach also allows specification of the appropriate variance structure of the response variable, while a log-transformed regression implicitly assumes that variance increases with the square of the mean; an assumption that appears incorrect for clam weights.

The curves from (NEFSC 2009) and the current assessment are not substantially different at common commercial meat weights though the current model predicts somewhat heavier meats at small shell lengths and lighter meats at large shell lengths (Figure A56.). The largest observed clam used in the model fitting was 190 mm. The curve for the current assessment was generated using a depth of 33 m, which is the average depth of the survey stations over all years used in the analysis.

Regional differences in meat weight are meaningful, though some of the differences between regions can be explained by the different depths found there (Figure A57.). The largest meats at length, given constant depth were found in Georges Bank, but the largest meats given the depths actually observed in each region were found in Southern New England.

Age and growth

Surfclams in age and growth samples were measured at sea and the shells were retained for aging in the laboratory. Shells for aging were collected based on a length stratified sampling plan. A recent study confirmed that rings on shells collected during the summer clam survey are annuli that can be used to estimate age (NEFSC 2009).

Age and length samples are available for most regions but not from every survey (Table A15). DMV and NJ were the most consistently sampled regions (Table A15). GBK was the least consistently sampled.

Plots of age vs. shell length by year and region (Figures A58 – A62) indicate that growth patterns have been relatively constant in most regions over time with DMV and NJ being notable exceptions. As described in the last assessment (NEFSC 2009), maximum size was lower after 1994 in DMV and NJ.

Von Bertalanffy parameters for growth in shell length were estimated for each region and each survey year for which sufficient data existed (Table A16). The Von Bertalanffy growth curve used in the calculations was:

$$L_a = L_\infty\left(1 - e^{(-K(a-t_0))}\right)$$

Where L_a is size (meat weight in g or SL in mm) at age a, and L_∞, K and t_0 are Von Bertalanffy parameters (the curves for growth in SL and weight have different parameter values). DMV and NJ have experienced significant declines in L_∞ through time. This result follows from weighted regression of the year specific parameter estimates against time, where the weights were the inverse standard errors of the parameters in question (Figures A63 - 64). NJ has experienced a significant decline in the growth constant K as well, demonstrating that clams in NJ are taking longer to reach a smaller size than they once did (Figure A65). Weighted regressions of parameter estimates in other regions did not indicate any significant trends over time.

Commercial LPUE

Commercial LPUE was not considered an adequate measure of relative abundance for this assessment because of the sessile nature of the species and the corresponding behavior exhibited by fishers. In general clam fishers use a fine spatial scale area until catch rates drop below economically profitable levels. They then move to another location and repeat the process. Thus catch rates tend to remain relatively stable over time even when population abundances fluctuate (See Appendix A2)

Stock Definitions (TOR-3)

Surfclams and ocean quahogs in the US EEZ (federal waters) have been managed as a single stock by the Mid-Atlantic Fishery Management Council for the last 35 years. The inshore portions of the resource off the coast of each state (<3 nm from shore) have been managed independently by state authorities. Two options for defining stocks in the EEZ surfclam resource were evaluated on technical grounds (biology, applicability of MSY reference points, fishing patterns and survey coverage) while excluding policy related considerations. The first (status-quo) option defines a single stock that extends over the entire range of the EEZ resource from Cape Hatteras in the south to the northern edge of Georges Bank. The second option defines two stocks by separating Georges Bank (GBK) from the area to the south along a traditional boundary based on NEFSC shellfish survey (depth) strata lines (Figure A66). The southern area (SNE - SVA) extends from Southern New England (just southwest GBK) in the north to Cape Hatteras in the Southern Virginia/North Carolina region in the south.

This discussion and TOR were triggered by difficulties noted in recent assessments (SARC 49 NEFSC 2010, page 43) and recommendations by SARC reviewers (SARC 49 summary report; NEFSC 2010, pages 9-11). The Invertebrate Working Group did not achieve consensus on this issue and so the decision about which approach is better is left to reviewers. Arguments for and against defining two stocks are presented in Table A17 – A18.

The working group did agree on a shared working definition of a stock for use in its deliberations. The definition, extracted from the NOAA Fisheries Glossary (Blackhart, et al. 2006; http://www.st.nmfs.gov/st4/documents/F_Glossary.pdf), reads:

> *A part of a fish population usually with a particular migration pattern, specific spawning grounds, and subject to a distinct fishery. A fish stock may be treated as a total or a spawning stock. Total stock refers to both juveniles and adults, either in numbers or by weight, while spawning stock refers to the numbers or weight of individuals that are old enough to reproduce.*[6]

Comment: In theory, a unit stock is composed of all the individual fish in an area that are part of the same reproductive process. It is self-contained, with no emigration or immigration of individuals from or to the stock. On practical grounds, however, a fraction of the unit stock is considered a "stock" for management purposes (or a management unit), as long as the results of the assessments and management remain close enough to what they would be on the unit stock.[5]

[5]*United Nations Food and Agricultural Organization. Fisheries Glossary.* http://www.fao.org/fi/glossary/default.asp

[6]*Northeast Fisheries Science Center. Definition of Fisheries Technical Terms. http://www.nefsc.noaa.gov/techniques/tech_terms.html*

Some recent developments in the fishery are relevant. The GBK region was closed to fishing due to risk of PSP contamination in 1990 and is nearly virgin. The fishing industry developed protocols during 2008-2011 for determining if PSP is present prior to fishing and subsequent laboratory testing once clams from GBK are landed. The protocols were tested during experimental fishing on GBK during 2011 and 2012 and have been approved. GBK will open for fishing by all permitted vessels during 2013. Industry sources expect landings from the GBK region will amount to about1 million bu per year (about 1/3 of recent landings) over the next few years.

Fishing on GBK involves long (multiday) trips by a small number of vessels (currently 3) which are substantially larger than the rest of the fleet, capable of fishing with two large dredges simultaneously and generally able to work under rough conditions. In contrast, smaller boats make day trips with a single and often smaller dredge in southern regions. The surfclam resource is believed to be lightly exploited.

Abundance has trended down in the south and up on GBK due to environmental effects but is near its target biomass as a whole. Under either the current or alternative stock definitions, surfclams are not likely to be overfished, nor is overfishing likely to be occurring.

Assessment model results (TOR 4)

Stock Synthesis (SS3[2]**)** replaced KLAMZ (Appendix A4) as the primary model in this assessment (Methot, in press). SS3 was preferable because it made better use of survey age data in estimating recruitment and in making forecasts. In addition, the SS3 model was more flexible and capable of handling multiple assessment areas as might be needed in future. SS3 models for surfclam were explored in the previous assessment, but the KLAMZ model was used to provide management advice (Appendix 2 in NEFSC 2010). KLAMZ models were updated for this assessment, and discussion and results, including the bridge to the current assessment, are available in Appendix A5.

Separate SS3 models were developed for surfclams in the southern and GBK areas. No final SS3 model is available for the combined southern plus GBK region assumed in KLAMZ models and previous assessments. Preliminary models that combined the two areas with no internal spatial subdivision were developed but abandoned after a great deal of work. Divergent population dynamics (i.e. different biomass and mortality trends, changes in proportion of total biomass in the two areas over time, very limited fishing on GBK, and differences in occurrence of strong year classes) made it too difficult to estimate "average" population dynamics for the areas combined. Also, data were lost when the areas were combined because surveys were not available for the entire combined assessment region in some years. In this assessment, biomass, fishing mortality,

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2 Stock Synthesis Model version SS-V3.24f compiled for 64-bit linux.

recruitment and other estimates for the combined regions were estimated by combining estimates for the southern and GBK areas.

Fishery and survey selectivity were functions of size rather than age in SS3 models (Table A20). Conditional ages at length data, rather than traditional age composition data, were used in fitting models. The conditional age vector with elements $n_{t,a,L}$ for example, gives the proportion or number of observed ages (a) from samples of length L in year t of the NEFSC clam survey. The major advantage of the conditional approach is that more information about growth (including variance in size at age) and yearclass strength is preserved. Size compostion data are not used twice (once as size composition data and once in calculation of traditional catch at age). Finally, the sampling distribution of condtional age data is probably easier and more accurately characterized as a multinomial conditional on the number of ages $n_{t,L}$ actually sampled. The traditional type of age data was included in the model for qualitative for use in evaluating goodness of fit and recruitment patterns. Traditional age composition data had no effect on model estimates.

The SS3 models for surfclams were more complex than KLAMZ, but relatively simple compared with many other SS3 models. We estimated fewer parameters relative to other models for many other species because NEFSC clam surveys are carried out every three years, the fishery is relatively uncomplicated, and because no other survey data were available (Table A20-A21). Simple approaches with relatively few parameters increased model stability, and aligned with the philosophy of KLAMZ models used in previous surfclam assessments. The same types of data were available for both areas, although more precise and numerous data were available for the southern area (Figures A68 – A69). The additional data for the south made it possible to estimate additional catchability and selectivity parameters, as well as biomass and mortality over a longer time period. It was necessary to borrow these parameter estimates from the south in modeling surfclams on GBK because data were so limited and catches were nearly zero.

Dome shaped survey selectivity curves with parameters fixed at field study estimates were used in SS3 models for surfclams in the south and on GBK. Field estimates were used because they were relatively precise, based on a great deal of data, and were obtained from designed experiments carried out in association with the stratified random survey using actual survey sampling gear (Figure A54). When survey selectivity parameters were estimated by SS3 in preliminary runs, different selectivity curves with broader domes were obtained. Estimating selectivity improved goodness of fit, but retrospective and other analyses indicated that model stability was substantially reduced. Moreover, field study survey selectivity estimates were relatively precise and were considered likely to be directly applicable to survey catches.

The number of trips sampled by port agents was used as initial effective sample sizes for fishery length data in each year. The number of survey tows that caught surfclams was used as initial effective sample size for survey size composition data in each year. The number of fish aged in each size group and year was used as the initial effective sample size for survey conditional catch at age data. Initial log scale standard deviations for survey abundance trend data were derived from the CV for mean numbers per tow in each year assuming that errors were lognormal. These initial specifications for length and age data were "tuned" (adjusted up or down) based on preliminary model fits by multiplying the values for each type of data by a constant that was the same for all observations of the same data type. The initial standard deviations for survey trend data were tuned based on preliminary model fits by adding a constant to the standard deviation for each observation in the time series.

In three anomalous cases for length data in the southern area (fishery length data for 1982 and 1989 and survey length data for 1984), effective samples sizes were fixed at a low value (effective N=10) to avoid distorting fit to the rest of the data in the model (see below). The survey length data for 1984 was anomalous because of a single very large catch of surfclams (the largest catch in the survey time series) that consisted almost entirely of 7-8.9 cm SL surfclams.

<u>Prior for survey dredge capture efficiency</u>

A prior distribution based on field study estimates of survey dredge capture efficiency was used to help estimate the catchability parameter for minimum swept area abundance from clam survey data. Survey dredge efficiency is key in estimating surfclam abundance in SS3, particularly because fishing mortality rates appear to be quite low (Figure A41). The model ignored the trend in swept-area abundance (likelihood weight=10^{-5}) but goodness of fit to the prior was included in the objective function. Catchability (q) and capture efficiency (e) are closely related:

$$I = qN$$
$$q = \frac{aeu}{A}$$

where I is mean number per tow in the survey, N is stock abundance (fully selected by the survey dredge for this derivation), A is stock area, a is the area swept by the dredge and u accommodates the change from survey units (mean number per standardized tow) to population abundance.

The time series of minimum survey swept-area abundance estimates (N') were developed assuming e=1 for use with the prior. These estimates were for surveys conducted beginning in 1997, when sensors were used to monitor dredge performance and to calculate area swept accurately. Minimum swept area abundance was calculated:

$$N' = \frac{AI}{au}$$

where survey mean number per tow (I) was calculated after adjusting the catches in each survey tow to a standard tow distance (a) based on sensor measurement of tow distance and after discarding a few tows with poor dredge performance due to problems identified using sensors (see TOR 2). Stock area (A) was the area covered by the survey (assumed to be the stock area) reduced by an estimate of the fraction of the stock area which is untowable by the survey dredge (untowable ground was assumed to be unsuitable habitat). In theory, catchability for the swept area abundance data is the same as capture efficiency because $q=N'/N=e$. Thus, the catchability coefficient from SS3 was an estimate of dredge capture efficiency that could be compared to the prior for capture efficiency based on field studies.

The prior for log efficiency in SS3 was normally distributed because the prior distribution for efficiency was lognormal. The original lognormal distribution had a mean of 0.234 and a CV of 1.304. The standard deviation of the normal prior for log efficiency was $\sigma = \sqrt{log(1 + CV^2)} = 0.997$ and the mean was $log(0.234) - 0.5\sigma^2 = -1.95$.

Comparing SS3 and KLAMZ

Care is required in comparing estimates from KLAMZ and SS3. Biomass results from SS3 were for ages 6+ (south) and 7+ (GBK where growth is slower) on January 1 (unless noted otherwise) to approximate the biomass of surfclams 12+ cm SL estimated in KLAMZ. Annual exploitation rates from SS3 were catch weights divided by biomass of ages 6+ (south) and 7+ (GBK) on January 1 and should be roughly comparable in both models.

Fishery selectivity assumptions and fishing mortality estimates differ in SS3 and KLAMZ and make comparisons more difficult. Fishing mortality rates were not comparable because estimates from SS3 related catch numbers to area abundance for fully recruited size groups (about 15-17 cm SL in the southern region and 14+ cm in GBK). Estimates from KLAMZ related catch weight to population biomass, assuming that all surfclams 12+ cm SL were fully recruited to the fishery.

Recruitment estimates from the two models were not comparable because recruitment was estimated as a smooth random walk in KLAMZ and as independent estimates around a constant mean in SS3. Age composition data used in SS3 were informative and made it possible to model recruitment in a more complicated and realistic manner. Moreover, recruitment was the biomass of clams 12-12.9 cm SL (approximately age 6 y) in KLAMZ and numbers of age 0 recruits on January 1 in SS3.

Issues

The primary issues encountered in using SS3 in preliminary runs for surfclams in the southern area were: 1) choice of growth parameters to be estimated, 2) fit to fishery size composition data for sizes 14+ cm SL, 3) lack of fit to survey data (overall trends as well as size composition data for 1982, 1983 and 1986), and 4) lack of fit to commercial size data for the largest surfclams. The most important issue in using SS3 for GBK surfclams was sparse data that limited estimation of key parameters and contributed additional uncertainty.

Decisions about growth parameters were important because growth assumptions were key elements in fitting the age structured SS3 model to commercial and survey size data and because growth has changed over time in the southern area. SS3 uses von Bertalanffy growth curves with five parameters. L_{min} was the predicted size at a_{min}, L_{max} was the predicted size at a_{max}, K was the von Bertalanffy growth rate parameter, where a_{min}=5 y and a_{max}=30 y are user specified ages. SD_{min} was the standard error in size for surfclams at age a_{min}, and SD_{max} was the standard error in size at age a_{max}. In addition, growth is assumed to linear between 0 and L_{min} for ages 0 to a_{min}. For GBK, growth parameters were assumed constant over time and fixed at estimates made externally from survey data.

L_{min}, L_{max} and K for the 1975-2006 cohorts in the southern area were estimated in three separate preliminary model runs as random walks. Cohorts born before 1975 or after 2006 were assumed to have the same growth curve as the 1975 or 2006 cohorts. Annual steps in the random walk were assumed to have log scale standard deviations of 0.05 so that parameters might change by about 5% per year on average. Results suggested relatively fast growth to large size (high K and L_{max}) for the 1978-1983 cohorts (Figure A70). The variability in L_{max} was unrealistically large (about 12-23 cm SL compared to about 16 cm SL from external estimates). The working group concluded that the apparent variability in L_{max} was probably due to anomalous survey size data for 1982-1984 and 1986 which remain unexplained (see below). In the absence of an explanation for the survey size data, growth parameters were assumed to be constant over time in the south. The group assumed that the obvious changes in growth after 1994 in the southern areas were relatively unimportant for the stock as a whole because abundance and biomass there was a relatively small fraction of the total after 1994.

Next, fifteen preliminary model runs were carried out estimating individual growth parameters or sets of growth parameters with all parameters assumed constant over time (Table A22 and Figure A71). External parameter estimates from growth curves were used as starting values for estimated parameters or for parameters not estimated. The two best models, based on total negative log likelihood (NLL) estimated relatively high L_{min}, low K values, and implausible growth curves. In contrast, the model with the third lowest NLL, which estimated L_{min} and L_{max} only, seemed to provide relatively good fit and a plausible growth curve. Therefore L_{min} and L_{max} were estimated in final SS3 models for the southern area with other growth parameters fixed at initial values.

SS3 did not fit survey trend data as well as initially expected based on KLAMZ model results (Figure 2 in Appendix A5). A sensitivity analysis was carried out with a preliminary model that used a large likelihood weight (λ=100) for survey fit. This caused the fit to the survey trend data to improve. Fit to all length and age data, however, degraded substantially (Table A23). Estimated trends were similar except during the late 1980s and early 1990s (Figure A72) The working group concluded that the survey trend data were relatively noisy and that SS3 did not fit the trend closely because there was no evidence in the length and age data that the variability in the survey trend was real.

Three sensitivity runs with a preliminary model were used to address lack of fit to the very peaked survey length composition data for 1982-1983 and 1986 in the southern area. Run 1 placed a high weight (λ=100) on all of the survey size data in the model. Run 2 increased the weight on just the 1982-1983 and 1986 survey size data by multiplying the assumed effective samples sizes by 10. Run 3 dropped the survey size data for 1982-1983 and 1986 entirely. The run with a high weight on all survey sizes indicated faster growth in area biomass to a higher level during the early 1980s. However, the working group noted that the lack of fit seemed relatively unimportant because: 1) biomass estimates for 1988-2011 were similar in all runs (Figure A73), 2) there were no problems fitting survey age data for 1982-1983 or 1986, and 3) the survey size data for 1984 (down weighted due to one large tow) were not as peaked as in the problematic years. Based on these considerations, the Working Group decided to include lack of fit to early survey size composition data as a research recommendation but to ignore it otherwise in SS3 models.

The lack of fit to commercial size composition data at large sizes (14-18 cm SL) suggests that natural mortality (M) increased for large surfclams or that commercial selectivity was dome shaped such that large clams were less likely to be caught. Natural mortality has been fixed at 0.15 in surfclam assessments since 2000 (NEFSC 2000, see appendix 7 in NEFSC 2009 for a discussion of M estimates for surfclam). Sensitivity analyses were run with a preliminary model that estimated natural morality rates for clams age 7+ y, 8+ y, etc. while maintaining $M=0.15\ y^{-1}$ for younger ages. The estimated natural mortality rates were always about $0.15\ y^{-1}$. These results indicate that the model was able to fit the survey age data (which show surfclams 30+ y in age routinely) reasonably well under the assumption that $M=0.15\ y^{-1}$ for all ages and size groups. In contrast, the lack of fit to commercial size composition data at large sizes was nearly eliminated when a dome-shaped fishery selectivity curve was estimated in the model.

The improvement in model fit with dome-shaped fishery selectivity in the south was puzzling. External estimates of commercial fishery selectivity based on field experiments indicate that the commercial clam dredges used to harvest surfclams (Figure A54) and ocean quahogs (Thorarinsdottir et al. 2010) have logistic, rather than domed fishery selectivity patterns. Industry contributors to the Working Group reported that clam dredges are designed to collect large surfclams with high efficiency because large clams provide a higher meat yield.

Based on these considerations, the Working Group concluded that the lack of large individuals in commercial samples from the southern area was probably due to removal of large surfclams by relatively heavy fishing on the productive grounds where the fishery is concentrated. In other words, the apparently domed relationship between length composition and fishery length samples from the southern area was probably due to logistic gear selectivity combined with removal of large clams (relative to the area as a whole) on fishing grounds.

Based on the considerations above, a dome shaped fishery selectivity pattern was estimated in the basecase model for the southern area. However, Georges Bank is essentially virgin. Therefore, the Working Group assumed that the fishery selectivity pattern for Georges Bank had the same shape (same parameters) as estimated for the southern area on the left hand side for small surfclams. The right hand side for large surfclams was assumed to be asymptotic resulting in a typical logistic selectivity pattern. No selectivity parameters were estimated for GBK because commercial size data for GBK were too few and too noisy.

<u>Fit and estimates from basecase models</u>

Goodness of fit for final basecase models (Tables A24) was generally good, with the exception of the early survey size composition data described above. The estimated catchability (survey dredge capture efficiency) estimate for swept area abundance in the south (e=0.33) was larger than the mode and mean of the experimentally derived prior (see TOR 2), but seems plausible. Fit to conditional age at length was good based on observed and predicted mean age and variance in ages at size, although there were patterns in bubble plots for age at length residuals (see Appendix A6). The models fit traditional survey age composition data very well even though they were not used in fitting the model, which relied on conditional age at length information. Strong year classes estimated by the models were clearly visible in the traditional age composition data, indicating that the conditional and traditional age data convey the same information. Full diagnostics of the model fit are available in Appendix A6.

In the southern area, biomass and fishing mortality were estimated with reasonable precision, while recruitment trends were relatively uncertain in recent years (Figures A74 – A76, Table A25). Biomass and recruitment were less precisely estimated in the northern area (Figures A77 – A79, Table A26).

<u>Likelihood profile analysis</u>

Likelihood profile analyses was an important uncertainty analysis that was carried out for surfclams in the southern area by fixing the catchability coefficient for the NMFS clam survey at successive values that bracketed the best estimate and estimating all of the other parameters in the model. To ease interpretation, results were presented in terms of the catchability coefficient for swept-area abundance in each run (i.e. for survey dredge efficiency). The profile was not carried out using dredge efficiency *per se* as the fixed variable for southern area runs because dredge efficiency interacts with its prior distribution. Instead, we report the dredge efficiency estimate that was obtained for each fixed value of clam survey catchability. Points where the negative log likelihood in profile analysis was the minimum value + 1.92 likelihood units were used to approximate 95% confidence bounds (Figure A80).

Likelihood profile results for the south indicate that goodness of fit for the survey trend was best near the basecase model run (Table A27). Fishery and survey length data support higher dredge efficiency estimates (lower biomass) while survey age data support lower dredge efficiency estimates (higher biomass). Biomass estimates were sensitive to dredge efficiency but trends and the status ratio (B2011/B1999) were not (Figure A80). The 95% confidence interval for dredge efficiency based on the profile analysis was about 0.24 to 0.43, the confidence interval for biomass was about 625,000 to 1,025,000 mt, and the confidence interval for B2011/B1999 was about 0.43 to 0.49 (Figure A80).

Preliminary runs showed that the likelihood surface for the GBK region was nearly the same over a relatively wide range of fixed dredge efficiency values. In other words, none of the data provided information about the overall abundance of GBK surfclams. Therefore, no likelihood profile analysis was performed for GBK and the working group concluded that biomass estimates for GBK were no more (and possibly much less) certain that the estimated dredge efficiency from the south.

Internal retrospective

The internal retrospective pattern for the southern area was minimal, Mohn's rho was only ρ = 0.02 for a nine year "peal" (after dropping nine 2002-2010) (Figure A81). The retrospective pattern in the GBK area was more substantial (Mohn's ρ = 0.30), but the confidence bounds of each successive peel overlapped considerably, indicating the retrospective probably did not constitute a substantial bias (Figure A82). Given limitations in the data for GBK (including no 2005 survey) it is not clear that better results could be expected.

Whole stock results

Whole stock biomass estimates for clams 12+ cm SL were the sum of the biomass estimates from each area $B_W = B_S + B_N$. Because the estimation error associated with the two areas was independent, the variance of the sum of the biomasses was $\sigma_W^2 = \sqrt{\sigma_N^2 + \sigma_S^2}$. Whole stock fishing mortality was $F_W = \frac{(C_S + C_N)}{(\bar{N}_S + \bar{N}_N)}$ where C_S and C_N were the catch in numbers from each area and $\bar{N}_S$ and $\bar{N}_N$ were average fully selected abundances $\bar{N} = \sum_L s_L \frac{N_L(1-e^{-Z_L})}{Z_L}$, where the total mortality rate (Z) was based only on fully selected lengths and s_L was commercial fishery size selectivity. Whole stock results are discussed in TOR 6 and are listed in Table A26B.

Historical retrospective

When the summary biomass estimates from both the northern and southern areas area were summed, the results were higher than biomass estimates from previous assessments (Table A28, Figure A83). Direct comparability is nuanced because the current assessment makes use of new data sources (e.g. age and size structure), and because the comparison of age 6+ (south) and 7+ (north) to animals greater than 12 cm is only approximately direct.

Older versions of the surfclam assessment used swept area biomass estimates as the primary means of determining stock status. These analyses were updated in appendix (A8).

Performance of historical projections

The previous assessment projected a combined GBK + south biomass of 868 thousand mt in 2011. This estimate was based on the "industry estimate" catch (20 – 23 thousand mt including incidental mortality). Actual catch was within this range. The current assessment estimated 1,100 thousand mt. The current estimate is outside the approximate 95% asymptotic confidence bounds (717 – 1,051 thousand mt) implied by the CV of the previous estimate (0.10). It is, however, difficult to compare forecast and current estimates because of the changes in estimates described above.

Updated and redefined biological reference points and scientific adequacy of existing and redefined BRPs (TOR 5)

According to the FMP for Atlantic surfclams, overfishing occurs whenever the annual fishing mortality rate on the entire (GBK + south) surfclam resource (stock) is larger than the over fishing limit (OFL). The OFL for Atlantic surfclam is based on the F_{MSY} proxy. The stock is overfished if total biomass falls below $B_{Threshold}$, which is estimated as ½ B_{MSY} proxy. When stock biomass is less than the biomass threshold, the fishing mortality rate threshold is reduced from F_{MSY} to zero in a linear fashion.

The current proxy for $F_{MSY} = M = 0.15$ y^{-1} was not revised in this assessment. However, its interpretation is revised because of the change in stock assessment models. In the KLAMZ model used previously, F=0.15 y^{-1} was effectively a biomass weighted mortality measure that corresponded (under certain conditions) to the standard abundance weighted mortality rates estimated in SS3. Moreover, fishery selectivity was assumed knife-edged at 120+ mm in KLAMZ but was estimated in SS3 to be dome-shaped with selectivity near one at sizes 160+ mm on GBK and 160-170+ mm SL in the south. At the OFL, all surfclams 120+ mm SL would experience F=0.15 based on the KLAMZ model but only surfclams 160+ or 160-170+ mm SL would experience F=0.15 based on the SS3 model. In effect, the OFL under SS3 is lower from a biological perspective than under KLAMZ. The potential split into two stocks (GBK and south) does not affect the current proxy because it can be applied under any set of stock definitions.

The current proxy for B_{MSY} in the current stock unit (GBK + south) is one-half of the estimated fishable biomass during 1999. The current proxy for $B_{Threshold}$ (which is used to identify overfished stocks) is B_{MSY} /2 or B_{1999}/4. Biomass in 1999 and related biological reference points under the current stock definition were re-estimated in this assessment (see below).

Current Stock Definition (GBK + southern areas)

Reference Point	Last assessment	Revised
F_{MSY}	M=0.15 y^{-1}	Same
B_{1999}	1086 thousand mt meats	1944 thousand mt meats
B_{MSY} =½B_{1999} (target)	543 thousand mt meats	972 thousand mt meats
$B_{Threshold}$ = ½ B_{MSY}	272 thousand mt meats	486 thousand mt meats
MSY	NA	98 thousand mt meats

The possible revision of the stock definition for surfclams which would separate GBK and the southern region complicates biological reference points to some extent. The Invertebrate Subcommittee noted that B_{1999} was almost identical (probably fortuitously) to estimated virgin biomass in the basecase SS3 model for the southern area and in sensitivity analysis and preliminary runs. The Subcommittee therefore agreed that B_{1999}/2 was still a suitable proxy for B_{MSY} in the southern region. The Subcommittee concluded that B_{1999} was preferable to a formal virgin biomass estimate from an assessment model as the basis for biomass reference points because the stability of estimated trends substantially reduces uncertainty in the ratio $B_{Current}/B_{Threshold}$ when $B_{Threshold} = B_{1999}/4$ and because of uncertainty about ongoing environmental trends. The group concluded that ratio of $B_{Current}$ over an estimate of B_{MSY} was thought unlikely to be robust particularly due to uncertainties about B_{MSY} in the face of environmental change.

The Invertebrate Subcommittee found no technical basis for establishing a B_{MSY} proxy for GBK. GBK is virgin, biomass has varied considerably there in the absence of fishing due presumably to environmental effects (Figure A77), and data for the GBK region is limited. The Subcommittee agreed that this uncertainty does not present any practical problems for determining legal status in this assessment because GBK is virgin and could not, by any definition, be overfished. Therefore, B_{MSY} for GBK is not defined but is considered an important research topic for the next assessment.

Southern Area

Reference Point	Last assessment	Revised
F_{MSY}	M=0.15 y^{-1}	Same
B_{1999}	1,086 thousand mt meats	1488 thousand mt meats
B_{MSY} =½B_{1999} (target)	543 thousand mt meats	744 thousand mt meats
$B_{Threshold}$ = ½ B_{MSY}	272 thousand mt meats	372 thousand mt meats
MSY	NA	74 thousand mt meats

Northern Area

Reference Point	Last assessment	Revised
F_{MSY}	M=0.15 y^{-1}	Same
B_{1999}	NA	NA
B_{MSY} =½B_{1999} (target)	NA	Undefined
$B_{Threshold}$ = ½ B_{MSY}	NA	Undefined
MSY	NA	29 thousand mt meats

Revised biomass reference points are higher than previous values primarily because of new information regarding the efficiency of the dredge used in NEFSC clam surveys and SS3 models that included age and length data. Conclusions about stock status are robust and would not change unless either the natural mortality estimate or biomass threshold was changed substantially.

Scientific adequacy of reference points

The current proxy for F_{MSY} (M = 0.15) is a common approach used in many fisheries. However, the productivity of the surfclam stock appears low for a species with M=0.15 and surplus production in surfclams may be negative for periods up to one or two decades. The performance of the simulated surfclam stock in projection analyses under the F_{MSY} proxy policy indicates that M=0.15 may not be an ideal proxy for F_{MSY} in the surfclam fishery. In addition, there is uncertainty about natural mortality in surfclams, which likely varies temporally and spatially. Reductions in biomass of surfclam in inshore southern regions are probably due, in part, to changes in environmental conditions and increasing natural mortality. On the other hand, the occurrence of old clams (> 35 y) in survey catches implies that the natural mortality rate may be lower than assumed. Sensitivity analysis indicated that the surfclam population in the south was adequately modeled using M=0.15. While there are indications that the current F_{MSY} proxy could be improved, there are no compelling reasons to change it at this time.

Stock status evaluation with respect to BRPs (TOR-6)

Current stock definition

The Atlantic surfclam stock in the US EEZ (current stock definition, GBK+south) has a low probability of being overfished ($B_{2011} > B_{Threshold}$) because the 95% confidence intervals for the biomass and reference point estimates do not overlap). The estimated stock biomass during 2011 for surfclams 120+ mm SL was 1060 thousand mt meats (CV=0.15) with a 95% confidence interval of approximately 791 to 1420 thousand mt meats. The biomass threshold is 1/4 of the biomass estimate for 1999; $B_{Threshold}$= 486 thousand mt meats (CV= 0.14) with a 95% confidence interval of 374 to 633 thousand mt meats (Figure A84, Table A29).

Surfclam biomass in 2011 was probably above its target biomass level ($B_{2011} < B_{Target}$) because the 95% confidence intervals for the target and current biomass levels do not overlap. The biomass target is ½ of the estimated biomass during 1999; B_{Target} = 972 thousand mt (CV 0.135) with a 95% confidence interval of 747 to 1235 thousand mt (Figure A84).

The Atlantic surfclam stock in the US EEZ is not experiencing overfishing ($F_{2011} < F_{MSY}$). Fishing mortality for the entire resource (F_W) was based on a numerically weighted average of the annual fishing mortality in each area, accounting for different selectivities. The estimated fishing mortality during 2011 was F= 0.027 y^{-1}, with 95% confidence intervals of (0.016 – 0.045), which is below the management threshold OFL of F = M = 0.15 y^{-1}. The confidence interval suggests that there is virtually no probability that F exceeded the OFL during 2011 (Figure A85, Table A30).

Alternative stock definition

The alternative stock definition would separate GBK and area to the south as separate stocks. There are no reference points currently defined for the GBK area (see TOR 5). The stock was not fished between 1989 and 2009 and is essentially virgin. Therefore the stock is not overfished and overfishing is not occurring.

The estimated stock biomass in the southern area during 2011 for surfclams age 6+ (~120+ mm SL) was 703 thousand mt meats (CV=0.2) with a 95% confidence interval of approximately 481 to 1028 thousand mt meats (Figure A74). The biomass threshold is 1/4 of the biomass estimate for 1999; $B_{Threshold}$= 392 thousand mt meats (CV= 0.17) with a 95% confidence interval of 268 to 516 thousand mt meats (Figure A86, Table A31). The confidence intervals associated with B2011 and the threshold reference point in the southern area overlap. Therefore there is a possibility that the southern area is overfished. Overfished probability was calculated using the approach detailed in Shertzer et al. (2008). The distributions for B_{2011} and $B_{THRESHOLD}$ were assumed to be log normal, with means equal to their point estimates and variances equal to their delta method variances (B_{2011}~LogN(6.55,0.194); $B_{THRESHOLD}$~LogN(5.92,0.167)). 10,000,000 possible threshold values were drawn from correlated distributions with means and variances as described above, where the correlation between them was equal to the correlation between $B_{THRESHOLD}$ and B_{2011} estimated in the model (0.90). Each pair of draws was compared. Overfished status occurred when the threshold draw was greater than the biomass draw. Probabilities were equal to the number of overfished occurrences divided by the number of comparisons made. The probability of being overfished was <1% (Figure A87).

The southern area is not experiencing overfishing ($F_{2011} < F_{MSY}$). The estimated fishing mortality during 2011 was F= 0.040 y^{-1}, with 95% confidence intervals of (0.025 – 0.056), which is below the management threshold OFL of F = M = 0.15 y^{-1}. The confidence interval suggests that there is virtually no probability that F exceeded the OFL during 2011 (Figure A88, Table A32).

Projections (TOR 7)

Basecase SS3 models were used to project biomass of surfclams approximately 120+ mm SL (age 6+ y in the south and 7+ y on GBK), landings (mt and bu), fully recruited fishing mortality, and annual exploitation rates (catch weight/biomass) in the southern area, GBK area, and the combined areas during 2012-2021 (Table A33 – A35 and Figures A89 – A95). Three harvest policies were assumed: 1) F=0.15 y^{-1} (at the OFL), 2) status-quo catch (23,357 mt y^{-1}, equivalent to landings of 20,854 mt or 2.7 million bu y^{-1}) and 3) the maximum allowed catch under the current FMP or "quota level" catch (29,359 mt y^{-1}, equivalent to 26,213 mt or 3.4 million bu y^{-1}) in the combined areas (Table A34).

There is a positive probability that the stock will be overfished within the next five years. The maximum probability of overfished status coincides with the minimum biomass estimate over the five year time horizon. Using the Shertzer et al. (2008) method, the probability of the whole stock being overfished ranged from 0.005 to 0.035, depending on the projection scenario being considered (Figure A96). Under the alternate stock definition the probability of the southern area being overfished in the next 5 years ranged from 0.015 – 0.044 (Figure A97).

The most likely fishing scenario is probably status quo, because the fishery is market limited and has been fishing under quota since 2004 (Table A2). The quota scenario is therefore a reasonable upper bound on likely fishing pressure over the next five years. Using the quota scenario and the maximum probability of being overfished in *any one year* in next five ($P*$ = 0.005, or 0.015, for the whole stock and southern area respectively) the cumulative probability of being overfished *at any time* during the next five years is $1 - \prod_y (1 - P_y^*)$ = 0.015 and 0.056 (Table A36), for the whole stock and southern area respectively, where P_y^* is the $P*$ value for each year (see Shertzer et al, 2008).

Catches were landings + 12% to account for assumed incidental mortality. Catches and landings during 2012 were assumed the same as during 2011. For lack of better information, catches on GBK during 2013-2021 were assumed to be the same in the status-quo catch and quota level catch scenarios. This assumption is likely reasonable for the first few years because of processor infrastructure and fleet range limitations. Thus, any differences in total catch between scenarios or over time would probably be due to differences in southern catches. Catches from GBK may, however, increase at some point if additional vessels capable of fishing on GBK, and additional processing infrastructure, are built in the north.

Projected total landings, biomass and exploitation levels for the combined area were obtained by adding estimates for the southern and GBK areas. Fishing mortality was not computed exactly for the combined area because fishery selectivity differs between the southern and GBK areas and numbers at size was not a projection output. Approximate fishing mortality was based on numerically weighted average fishing mortality from each area.

Projected fishing mortality levels are lower than the fishing mortality threshold F=0.15 y^{-1} for the entire resource under the current stock definition under all scenarios except F=M=OFL (Figure A91; Table A36). Under the alternative stock definition, neither the southern area nor the GBK area are likely to experience overfishing under the status quo or quota scenarios (Figures A93 and A95; Table A36).

Probability distributions of the catch at the OFL were generated by repeated draws from the sampling distribution of biomass in each year. B_i, the biomass in year i was assumed to have a log normal distribution $B_i \sim Lognormal(\beta_i, \sigma_i)$, where β_i is point estimate of biomass in year i and σ_i is the delta method standard deviation estimated in the model for biomass in year i. The overfishing limit F=M=0.15 was applied to each of 1,000,000 draws from the distribution for B_i, resulting in a probability distribution of catch (Figures A98 – A200; Table A37).

Additional sensitivity analyses and decision tables based on projections are available in appendix A9.

Research recommendations (TOR 8)

The following are previous research recommendations (not in priority order):

i) Continue surfclam recruitment research. *This assessment incorporates length and age data. Age structure provides some new information that was not previously leveraged in forecasting. This change should allow for more precise estimation of the magnitude of incoming year classes and thus improve our ability to predict important recruitment events. Including age and size structure have also broadened the scope of hindcast recruitment analysis by allowing the inclusion of younger ages into the assessment model. Recruits in the old assessment were animals approximately five years old. We now use age zero animals.*

ii) Port samples should be taken from the SNE and GBK (if fishing resumes there) regions. *Collected since 2010.*

iii) Determine how much of Georges Bank is good surfclam habitat, and if depletion and selectivity experiments done in the mid-Atlantic are applicable to the Georges Bank region. *We have begun exploratory work with existing HabCam**3** images, attempting remote identification of bivalves using siphon anatomy. We hope that automated identification of live surfclam is possible and will lead to a better understanding of habitat use by surfclam. If this turns out to be too difficult it is possible that visual inspection of HabCam images will lead to habitat identification through other means, such as identifiable shell piles or shell hash. This project is still in exploratory stages, though we have applied twice for funding.*

iv) Fecundity and maturity at length information is required to improve reference point calculations and predict management effects. *No progress. This issue is technically difficult to resolve in situ and is unlikely to be addressed in the near term. Direct studies of fecundity would require specialized laboratory facilities. It is possible that academic partners may pursue this research topic.*

v) Data on the number of clams per bushel landed at different ports over time would be useful. *No progress.*

vi) Commercial length data for surfclams should be more accessible. *Commercial length data is summarized in this document and is available by request through NEFSC.*

vii) Determine whether the carrying capacity of surfclams has changed over time. *No progress. Surfclam are experiencing a range contraction as habitat degrades in the southern extreme of the historical species extent due to climate change. Carrying capacity has certainly changed over time, and clearly continues to change, though this topic has not been directly addressed analytically.*

viii) Estimate densities of spawning surfclams necessary to produce good recruitment. Is reproduction likely to be impaired if relatively dense beds of surfclams are reduced? *No progress.*

New research recommendations (not in priority order)

i) Biomass reference points need to be reconsidered.
ii) Has surfclam biomass shifted offshore into deeper water over time?
iii) Look into a better way to implement regime change into the SS3 model. Look into patterns which may match other species and climate indices.
iv) Determine the best spatial and temporal distribution to use for surfclam assessment models
v) Look at habitat on GBK

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3 See http://habcam.whoi.edu

vi) Given the increasing importance of GBK re-evaluate the optimal sampling design for the survey.
vii) Look into area specific recruitment streams for SS3 and how to accommodate the 2012 and 2013 surveys.

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Table A1. Surfclam discard estimates from 1982 through 1994. A minimum size regulation was in effect from 1982 through 1990. Within two years of dropping the minimum size regulation (1993) the discard rate had dropped to zero and has remained zero since then.

Year	Discard (mt meats)					Landings (mt meats)	Discards / Landings	Catch	Size limit (mm)
	NNJ	SNJ	NJ	DMV	Total				
1982	3,684	215	3,899	2,295	6,194	16,688	37%	22,882	140
1983	2,122	385	2,507	2,127	4,634	18,592	25%	23,226	140
1984	2,266	458	2,724	2,015	4,739	22,888	21%	27,627	133
1985	1,938	248	2,186	1,725	3,911	22,480	17%	26,391	127
1986	2,328	233	2,561	239	2,800	24,520	11%	27,320	127
1987	1,414	61	1,475	415	1,890	21,744	9%	23,634	127
1988	1,317	13	1,330	106	1,436	23,377	6%	24,813	127
1989	1,048	6	1,054	258	1,312	21,887	6%	23,199	127
1990	1,089	57	1,146	123	1,269	24,018	5%	25,287	127
1991	495	36	531	5	536	20,615	3%	21,151	--
1992	918	102	1,020	4	1,024	21,685	5%	22,709	--
1993	0	0	0	0	0	21,859	0%	21,859	--
1994	0	0	0	0	0	21,942	0%	21,942	--

Table A2. (Following page) Atlantic surfclam landings and EEZ surfclam quotas. All figures are meat weights in mt. Total landings for 1965-1981 are from NEFSC (2003) and while figures for other years were from a dealer database (CFDBS). EEZ landings for 1965-1982 are from NEFSC (2003) while figures from later years are from a logbook database (SFOQVR). Landings for state waters are total landings - EEZ landings.

Year	Total (dealer data)	EEZ (logbooks)	State waters (dealer-logbooks)	Proportion from EEZ	EEZ Quota
1965	19,998	14,968	5,030	0.75	
1966	20,463	14,696	5,767	0.72	
1967	18,168	11,204	6,964	0.62	
1968	18,394	9,072	9,322	0.49	
1969	22,487	7,212	15,275	0.32	
1970	30,535	6,396	24,139	0.21	
1971	23,829	22,704	1,125	0.95	
1972	28,744	25,071	3,673	0.87	
1973	37,362	32,921	4,441	0.88	
1974	43,595	33,761	9,834	0.77	
1975	39,442	20,080	19,362	0.51	
1976	22,277	19,304	2,973	0.87	
1977	23,149	19,490	3,659	0.84	
1978	17,798	14,240	3,558	0.8	13,880
1979	15,836	13,186	2,650	0.83	13,880
1980	17,117	15,748	1,369	0.92	13,882
1981	20,910	16,947	3,963	0.81	13,882
1982	21,727	16,688	5,039	0.77	18,506
1983	23,631	18,592	5,038	0.79	18,892
1984	30,530	22,889	7,641	0.75	18,892
1985	28,316	22,480	5,835	0.79	21,205
1986	35,073	24,521	10,552	0.7	24,290
1987	27,231	21,744	5,486	0.8	24,290
1988	28,506	23,378	5,128	0.82	24,290
1989	30,081	21,888	8,194	0.73	25,184
1990	32,628	24,018	8,610	0.74	24,282
1991	30,794	20,615	10,179	0.67	21,976
1992	33,164	21,686	11,478	0.65	21,976
1993	32,878	21,859	11,019	0.66	21,976
1994	32,379	21,943	10,436	0.68	21,976
1995	30,061	19,627	10,434	0.65	19,779
1996	28,834	19,827	9,008	0.69	19,779
1997	26,311	18,612	7,700	0.71	19,779

1998	24,506	18,234	6,272	0.74	19,779
1999	26,677	19,577	7,100	0.73	19,779
2000	31,093	19,778	11,315	0.64	19,779
2001	31,237	22,017	9,220	0.7	21,976
2002	32,645	24,006	8,639	0.74	24,174
2003	31,526	25,017	6,509	0.79	25,061
2004	28,322	24,197	4,125	0.85	26,218
2005	26,882	21,163	5,719	0.79	26,218
2006	27,176	23,573	3,604	0.87	26,218
2007	27,094	24,915	2,179	0.92	26,218
2008	27,750	22,519	5,231	0.81	26,218
2009	22,972	20,149	2,823	0.88	26,218
2010	19,978	18,102	1,876	0.91	26,218
2011	19,908	18,587	1,320	0.93	26,218
Min	15,836	6,396	1,125	0.21	13,880
Max	43,595	33,761	24,139	0.95	26,218
Mean	27,022	19,983	7,039	0.75	21,850

Table A3. EEZ surfclam landings (mt meats) by stock assessment area and year prorated based on NEFSC (2003) for 1979 and logbook data for 1980-2011. Landings from unknown areas in each year were prorated to known areas based on logbook proportions of landings in known areas.

Year	SVA	DMV	NJ	LI	SNE	GBK	Other	Total EEZ
1979	0	11,836	1,350	0	0	0	0	13,186
1980	64	12,788	2,878	17	0	0	0	15,748
1981	568	7,472	8,820	88	0	0	0	16,947
1982	1,705	6,679	8,086	94	125	0	0	16,688
1983	2,225	7,173	8,095	264	836	0	0	18,592
1984	1,797	5,979	11,905	7	382	2,766	54	22,889
1985	741	7,856	11,246	0	452	2,185	0	22,480
1986	529	2,853	17,730	17	1,223	1,991	177	24,521
1987	378	1,303	18,017	0	1,140	907	0	21,744
1988	558	1,149	19,420	0	1,512	739	0	23,378
1989	439	3,123	16,532	0	1,361	433	0	21,888
1990	1,502	3,546	17,887	0	998	7	79	24,018
1991	0	1,634	18,913	15	33	0	21	20,615
1992	0	1,221	20,399	61	5	0	0	21,686
1993	0	3,414	18,365	62	3	0	14	21,859
1994	0	3,454	18,418	71	0	0	0	21,943
1995	0	2,752	16,497	0	378	0	0	19,627
1996	0	2,239	17,479	26	82	0	0	19,827
1997	0	1,540	16,999	73	0	0	0	18,612
1998	0	484	17,511	117	121	0	0	18,234
1999	0	648	18,755	157	16	0	0	19,577
2000	0	2,042	17,513	121	103	0	0	19,778
2001	0	3,282	17,719	935	81	0	0	22,017
2002	64	4,489	18,271	1,130	52	0	0	24,006
2003	0	1,432	21,693	1,625	267	0	0	25,017
2004	0	1,482	19,197	906	2,612	0	0	24,197
2005	0	1,668	16,850	759	1,885	0	0	21,163
2006	0	2,773	19,660	245	895	0	0	23,573
2007	0	3,073	20,268	1,117	458	0	0	24,915
2008	0	3,261	17,517	1,317	423	0	0	22,519
2009	0	1,978	14,881	1,827	1,451	11	0	20,149
2010	0	1,583	11,144	1,184	2,888	1,302	0	18,102
2011	0	1,427	11,908	437	2,420	2,397	0	18,587
Min	0	484	1,350	0	0	0	0	13,186
Max	2,225	12,788	21,693	1,827	2,888	2,766	177	25,017
Mean	320	3,565	15,513	384	673	386	10	20,851

Table A4. EEZ fishing effort (hours fished by all vessels) for surfclam, by stock assessment area and year based on logbook data. The fraction of logbook effort from unknown areas in each year was prorated to known areas based on effort in known areas. Effort data prior to 1981 are less reliable due to restrictions on hours fished per day.

Year	SVA	DMV	NJ	LI	SNE	GBK	Other	Total EEZ
1982	2,790	18,050	24,636	225	137	0	0	45,838
1983	4,191	18,805	23,584	536	1,130	0	0	48,245
1984	2,603	8,972	20,819	27	1,264	1,732	42	35,459
1985	397	4,686	10,518	0	1,702	2,608	0	19,911
1986	236	1,629	10,764	38	2,516	1,610	675	17,469
1987	262	722	11,910	0	3,780	1,006	0	17,680
1988	322	593	13,175	0	5,274	587	0	19,950
1989	228	1,615	11,794	0	4,741	389	0	18,768
1990	1,150	2,065	12,437	0	3,032	0	898	19,582
1991	0	1,254	17,243	21	107	0	293	18,917
1992	0	797	21,379	67	0	0	0	22,243
1993	0	2,423	18,232	57	15	0	5	20,731
1994	0	1,930	21,495	70	0	0	0	23,495
1995	0	1,560	18,625	0	1,059	0	0	21,244
1996	0	1,577	20,994	40	287	0	0	22,899
1997	0	1,098	20,383	77	0	0	0	21,558
1998	0	289	19,608	134	518	0	0	20,550
1999	0	734	18,146	151	149	0	0	19,180
2000	0	1,859	16,787	115	368	0	0	19,128
2001	0	2,536	18,461	962	148	0	0	22,108
2002	112	5,505	19,826	1,241	62	0	0	26,747
2003	0	2,367	25,034	1,828	176	0	0	29,405
2004	0	3,161	26,409	1,244	1,093	0	0	31,907
2005	0	2,654	24,379	1,207	1,364	0	0	29,604
2006	0	5,883	27,102	343	1,022	0	0	34,350
2007	0	7,065	34,664	1,587	960	0	0	44,276
2008	0	8,154	33,916	2,308	541	0	0	44,920
2009	0	5,669	33,648	4,195	2,528	12	0	46,053
2010	0	4,201	32,103	3,314	5,614	479	0	45,712
2011	0	3,067	35,043	1,361	7,339	1,084	0	47,894
Min	0	289	10,518	0	0	0	0	17,469
Max	4,191	18,805	35,043	4,195	7,339	2,608	898	48,245
Mean	410	4,031	21,437	705	1,564	317	64	28,527

Table A5. Real and nominal prices for surfclams based on dealer data. Average price was computed as total revenues divided by total landed meat weight during each year, rather than as annual averages of prices for individual trips, to reduce bias due to small deliveries at relatively high prices. The consumer price index (CPI) used to convert nominal dollars to 2010 equivalent dollars is for unprocessed and packaged fish, which includes shellfish and finfish.

Year	CPI	Prices ($ / bu)		Revenue (million $)	
		Nominal	Real ($2010)	Nominal	Real ($2010)
1982	0.50	8.94	17.89	25.186	50.406
1983	0.52	7.57	14.58	23.207	44.678
1984	0.54	8.37	15.54	33.156	61.521
1985	0.56	9.34	16.82	34.303	61.780
1986	0.57	9.20	16.21	41.841	73.725
1987	0.58	7.83	13.40	27.644	47.336
1988	0.60	7.80	12.91	28.826	47.721
1989	0.63	7.78	12.40	30.330	48.384
1990	0.65	7.66	11.76	32.393	49.755
1991	0.67	7.51	11.13	29.975	44.464
1992	0.69	7.40	10.72	31.832	46.125
1993	0.71	7.83	11.10	33.369	47.307
1994	0.72	9.82	13.64	41.241	57.261
1995	0.74	10.58	14.39	41.246	56.098
1996	0.75	10.24	13.66	38.275	51.085
1997	0.76	10.31	13.53	35.189	46.151
1998	0.77	9.19	11.92	29.200	37.869
1999	0.78	8.79	11.24	30.421	38.881
2000	0.80	9.43	11.80	38.025	47.568
2001	0.82	9.76	11.95	39.555	48.390
2002	0.83	9.45	11.37	39.988	48.141
2003	0.85	9.64	11.37	39.427	46.487
2004	0.87	9.59	10.99	35.209	40.377
2005	0.90	9.50	10.55	33.123	36.764
2006	0.93	10.19	10.95	35.908	38.608
2007	0.96	10.49	10.96	36.844	38.497
2008	0.98	10.96	11.20	39.441	40.316
2009	0.99	11.43	11.56	34.050	34.442
2010	1.00	11.67	11.67	30.240	30.240
2011	1.02	11.52	11.28	29.732	29.110

Table A6. Nominal landings per unit effort (LPUE, bushels h^{-1}) for surfclam fishing (all vessels) in the US EEZ from logbooks. LPUE is defined as total landings in bushels divided by total hours fished. Landings and fishing effort from unknown areas were prorated to area before LPUE was calculated.

Year	SVA	DMV	NJ	LI	SNE	GBK	Other	All areas
1982	79	48	43	54	118			47
1983	69	49	45	64	96			50
1984	89	86	74	35	39	207	165	84
1985	242	217	139		34	109		146
1986	291	227	214	59	63	160	34	182
1987	187	234	196		39	117		159
1988	224	251	191		37	163		152
1989	249	251	182		37	144		151
1990	169	223	187		43		11	159
1991		169	142	95	40		9	141
1992		199	124	119				126
1993		183	131	143	28		390	137
1994		232	111	132				121
1995		229	115		46			120
1996		184	108	85	37			112
1997		182	108	122				112
1998		217	116	114	30			115
1999		115	134	135	14			132
2000		142	135	137	36			134
2001		168	124	126	71			129
2002	74	106	120	118	108			116
2003		78	112	115	197			110
2004		61	94	94	310			98
2005		82	90	82	179			93
2006		61	94	93	114			89
2007		56	76	91	62			73
2008		52	67	74	101			65
2009		45	57	56	74	120		57
2010		49	45	46	67	352		51
2011		60	44	42	43	287		50
Min	74	45	44	42	14	120	9	50
Max	74	232	142	143	310	352	390	141
Mean	74	127	102	101	86	253	199	104

Table A7. Numbers of commercial trips sampled and numbers of surfclams measured in port samples from landings during 1982-2011, by region. Numbers of trips during 1982-1999 were estimated assuming 30 individuals sampled per trip, as specified in port sample instructions.

	DMV		NJ		LI		SNE		GBK	
Year	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths
1982	259	7756	249	7477	1	30				
1983	197	5923	375	11253	Unk.	Unk.	1	30		
1984	102	3066	425	12751	3	90				
1985	61	1832	256	7674	5	150				
1986	42	1260	171	5130	11	330				
1987	24	730	30	900	19	569				
1988	14	420	30	900	27	810				
1989	29	866	31	919	15	449				
1990	30	892	30	901	7	209				
1991	36	1080	76	2272						
1992	39	1170	57	1710						
1993	46	1392	31	928	Unk.	Unk.				
1994	4	119	30	900						
1995	24	720	17	510						
1996	38	1154	37	1117						
1997	54	1622	32	957						
1998	52	1560	23	690						
1999	57	1720	29	856						
2000	20	600	111	3315	1	30				
2001	33	970	42	1260						
2002	7	210	37	1111						
2003	2	60	80	2455	5	150				
2004	36	1080	2	60						
2005	19	581	61	1834	11	330				
2006	50	1541	49	1482	23	690				
2007	68	2215	72	2409	16	508				
2008	57	1712	65	1950	21	632				
2009	31	932	59	1771	43	1296				
2010	25	751	43	1293	36	1086	3	90	15	450
2011	28	780	126	3706	52	1460	70	2097	7	240
Min	2	60	17	510	1	30	1	30	7	240
Max	259	7,756	425	12,751	23	690	27	810	15	450
Mean	53	1,584	92	2,768	11	343	10	296	11	345

Table A8. Number of successful random tows in NEFSC clam surveys used for survey trends and efficiency corrected swept area biomass. "Holes" (unsampled survey strata in some years) were filled by borrowing from adjacent surveys were possible (borrowed totals are negative numbers in gray-shaded boxes). Holes that could not be filled have zeros in black boxes. Survey strata are grouped by region. Survey strata not used for surfclams are not shown.

	Years												
Stratum	**1982**	**1983**	**1984**	**1986**	**1989**	**1992**	**1994**	**1997**	**1999**	**2002**	**2005**	**2008**	**2011**
							SVA						
1	**-10**	10	14	7	10	10	10	10	**-10**	0	0	0	0
2	0	0	0	**-1**	1	2	1	1	**-1**	0	0	0	0
5	4	9	13	8	8	8	7	8	**-16**	8	8	**-17**	9
6	1	1	1	1	1	1	1	1	**-3**	2	1	**-1**	0
80	**-6**	6	9	3	7	7	8	7	**-7**	0	0	0	0
81	**-4**	4	7	3	5	5	5	5	**-10**	5	**-10**	5	0
							DMV						
9	30	26	35	29	37	37	38	37	37	38	37	31	15
10	2	2	3	3	3	3	3	3	3	3	3	2	4
13	19	18	25	20	20	20	21	20	19	20	18	15	7
14	2	2	3	3	3	3	5	3	3	3	3	**-26**	23
82	1	1	1	1	1	1	1	1	2	2	**-3**	1	0
83	2	2	2	2	2	2	2	2	2	2	2	2	0
84	4	3	3	4	4	4	4	4	3	4	4	4	4
85	5	5	4	5	5	5	5	5	5	5	5	5	5
86	2	2	3	3	3	2	3	3	3	3	3	3	5
							NJ						
17	11	11	18	12	12	12	12	12	12	12	12	12	5
18	3	3	**-6**	3	3	3	3	3	3	3	3	3	5
21	18	18	22	19	20	20	20	20	33	27	20	28	15
22	3	3	**-6**	3	3	3	5	3	3	3	3	3	5
25	9	9	13	8	9	9	9	9	8	9	9	13	8
26	2	2	**-5**	3	3	3	3	3	3	3	3	3	3
87	8	7	10	9	9	9	9	9	9	16	8	9	6
88	15	15	24	17	20	20	20	21	21	20	17	19	6
89	15	15	21	15	18	17	18	19	18	18	15	18	4
90	2	2	3	2	2	2	2	2	2	2	2	1	4

Table A8. Cont...

	Years												
Stratum	**1982**	**1983**	**1984**	**1986**	**1989**	**1992**	**1994**	**1997**	**1999**	**2002**	**2005**	**2008**	**2011**
							LI						
29	11	10	**-20**	10	10	10	10	10	10	10	10	16	10
30	7	8	**-14**	6	6	6	6	6	5	6	7	12	4
33	4	4	**-8**	4	4	4	5	4	4	4	4	10	4
34	2	2	**-4**	2	2	2	5	2	1	2	2	8	6
91	3	2	4	4	3	3	3	3	3	3	3	5	11
92	2	2	3	2	2	2	2	2	2	2	2	5	11
93	1	2	2	1	1	1	1	1	1	2	1	4	6
							SNE						
37	7	4	**-7**	3	**-6**	3	5	4	4	3	**-3**	3	2
38	3	2	**-5**	3	3	3	5	3	3	3	2	3	7
41	6	5	7	5	6	6	6	6	5	6	6	6	4
45	3	7	9	4	4	4	4	4	4	2	4	4	7
46	2	5	5	3	2	3	5	3	3	2	3	3	6
47	4	3	4	2	2	4	4	4	3	1	7	4	8
94	1	2	**-2**	0	**-1**	1	2	2	**-4**	2	**-2**	2	5
95	4	14	11	4	4	4	4	4	4	4	**-8**	4	5
96	**-12**	12	**-13**	1	1	3	2	4	**-4**	0	**-1**	1	0
							GBK						
54	0	**-3**	3	3	**-6**	3	3	3	**-3**	0	**-2**	2	2
55	3	**-3**	**-3**	3	1	3	3	3	2	2	**-4**	2	3
57	0	0	**-2**	2	1	2	5	2	2	2	**-4**	2	11
59	1	4	**-5**	1	2	6	5	5	4	5	**-9**	4	16
61	8	1	**-6**	5	**-12**	7	5	6	6	6	**-11**	5	5
65	0	0	**-3**	3	**-5**	2	4	3	**-4**	1	**-1**	1	3
67	0	**-5**	5	5	7	7	7	7	**-7**	0	**-2**	2	1
68	1	**-8**	7	3	6	6	5	5	**-5**	0	**-6**	6	0
69	2	5	**-11**	6	6	6	7	6	8	**-8**	**-4**	4	1
70	1	2	**-6**	4	**-8**	4	4	4	3	2	**-6**	4	19
71	0	**-2**	2	3	1	2	3	3	1	2	**-3**	1	3
72	2	**-10**	8	1	8	8	8	8	6	**-6**	**-4**	4	5
73	1	1	**-4**	3	6	6	6	6	5	6	**-9**	3	5
74	3	**-4**	1	3	**-7**	4	4	4	3	3	**-6**	3	11

Table A9. NEFSC clam survey stations for which the model predicted differential pressure below the threshold (35 PSI) for more than 25% of fishing seconds. These stations were not used in the current assessment.

Station	Strata	Depth	Lat	Lon	Region
143	13	42	38.27442	74.5733	DMV
145	14	54	38.30777	74.23925	DMV
70	87	27	39.06597	74.40457	NJ
254	26	48	39.88967	73.32147	NJ
46	26	65	40.14597	73.65233	NJ
31	29	33	40.43415	73.34963	LI
292	38	55	40.91837	71.60237	SNE
294	37	39	41.27432	71.40202	SNE
481	94	28	41.3911	71.23802	SNE
482	94	28	41.44353	71.38292	SNE
343	57	70	40.81365	68.01625	GBK
342	57	65	40.84938	68.01197	GBK
341	57	64	40.85402	68.0533	GBK
375	59	62	40.90093	67.91472	GBK
376	70	53	40.97942	67.84257	GBK
377	70	57	40.98083	67.77793	GBK
394	59	73	41.022	67.17712	GBK
390	59	59	41.10465	67.51712	GBK
391	59	58	41.14662	67.4156	GBK
409	73	46	41.43885	67.35357	GBK
419	74	53	41.79002	67.36272	GBK
430	72	54	41.9348	67.45007	GBK
180	23	55	38.89438	73.53642	OTH

Table A10. (On the following pages.) NEFSC clam survey data for surfclam abundance (mean N/tow) and biomass (mean kg/tow). Data are for three size groups: prerecruits (50-119mm), fishable clams (120+mm) and all clams greater than 50mm. Survey holes (strata with no sampling) are filled by borrowing, but no imputed data were used for this table.

		Prerecruits (50-119 mm SL)				**Large fishable (120+ mm SL)**				**All surfclams 50mm and above**						
	Year	N / Tow	CV	KG / Tow	CV	N / Tow	CV	KG / Tow	CV	N / Tow	CV	KG / Tow	CV	N Tows	Pos. Tows	N Strata
	1982	3.53	0.88	0.19	0.90	3.73	0.92	0.404995	0.86	7.26	0.90	0.595757	0.872	25	6	5
	1983	6.60	0.62	0.35	0.64	5.71	0.62	0.649399	0.59	12.31	0.58	0.994758	0.565	30	12	5
	1984	7.85	0.37	0.43	0.40	21.82	0.31	2.536182	0.294	29.66	0.30	2.961469	0.287	44	17	5
	1986	1.50	0.35	0.08	0.42	22.20	0.75	2.413548	0.735	23.69	0.72	2.495099	0.72	23	13	6
	1989	3.11	0.75	0.11	0.70	9.78	0.83	1.199442	0.819	12.89	0.81	1.310352	0.808	32	13	6
	1992	18.15	0.86	1.22	0.91	12.10	0.77	1.279377	0.783	30.25	0.65	2.497773	0.648	33	18	6
SVA	1994	43.38	0.46	1.03	0.31	6.38	0.44	0.656494	0.355	49.76	0.40	1.689041	0.276	33	19	6
	1997	10.31	0.44	0.42	0.46	0.49	0.46	0.047867	0.44	10.80	0.43	0.4673	0.448	32	14	6
	1999	9.32	0.41	0.33	0.36	1.22	0.46	0.134403	0.473	10.54	0.38	0.460503	0.331	47	21	6
	2002	13.69	0.61	0.49	0.62	5.66	0.55	0.641627	0.55	19.35	0.58	1.132064	0.565	15	7	3
	2005	3.65	0.66	0.07	0.57	0.00	0.00	0	0	3.65	0.66	0.068276	0.573	14	4	3
	2008	10.23	0.30	0.24	0.29	0.00	0.00	0	0	10.30	0.29	0.24407	0.286	18	11	2
	2011	15.40	0.29	0.38	0.28	0.14	1.00	0.010603	1	15.54	0.29	0.395325	0.27	9	8	1
	1982	157.13	0.46	9.58	0.46	21.36	0.23	3.524782	0.32	178.49	0.42	13.10507	0.407	68	47	9
	1983	30.68	0.54	1.98	0.62	31.21	0.46	3.855335	0.364	61.88	0.49	5.831617	0.439	61	41	9
	1984	184.10	0.74	6.94	0.62	34.91	0.28	4.327025	0.276	219.01	0.63	11.26841	0.395	79	58	9
	1986	58.77	0.43	3.99	0.46	74.79	0.38	8.290292	0.326	133.56	0.39	12.278	0.365	70	53	9
	1989	16.71	0.54	1.02	0.55	31.24	0.26	3.782973	0.245	47.94	0.26	4.807792	0.233	78	53	9
	1992	13.49	0.28	0.75	0.38	28.86	0.29	3.591607	0.242	42.35	0.28	4.339855	0.258	77	58	9
DMV	1994	68.70	0.33	3.57	0.43	60.96	0.21	7.35485	0.201	129.67	0.23	10.92903	0.218	83	66	9
	1997	77.18	0.17	4.30	0.20	54.53	0.24	6.127452	0.225	131.71	0.17	10.42328	0.19	82	64	9
	1999	29.61	0.28	1.94	0.28	26.36	0.22	3.002235	0.205	55.98	0.23	4.939529	0.21	78	47	9
	2002	16.47	0.28	0.75	0.27	20.70	0.21	2.756585	0.192	37.17	0.22	3.511343	0.186	81	58	9
	2005	6.44	0.42	0.31	0.43	4.76	0.26	0.616634	0.282	11.19	0.27	0.922988	0.237	75	45	9
	2008	9.61	0.23	0.36	0.25	2.64	0.35	0.361625	0.348	12.34	0.23	0.729765	0.266	89	50	9
	2011	43.27	0.25	1.78	0.29	9.32	0.40	0.98473	0.427	51.92	0.26	2.690627	0.309	66	37	9
	1982	33.10	0.30	2.18	0.32	32.78	0.22	4.690181	0.212	65.88	0.19	6.874827	0.178	85	60	10
	1983	27.78	0.51	1.88	0.55	25.38	0.22	3.434296	0.207	53.16	0.30	5.319006	0.251	85	63	10
NJ	1984	15.93	0.23	0.80	0.23	29.97	0.20	4.038403	0.186	45.90	0.18	4.835422	0.179	126	86	10
	1986	10.33	0.21	0.55	0.21	29.68	0.18	4.44884	0.18	40.01	0.17	4.999115	0.17	91	70	10
	1989	9.88	0.29	0.52	0.30	31.53	0.15	4.439793	0.134	41.40	0.15	4.964282	0.135	99	75	10

	Year	N / Tow	CV	KG / Tow	CV	N / Tow	CV	KG / Tow	CV	N / Tow	CV	KG / Tow	CV	N Tows	Pos. Tows	N Strata
	1992	16.46	0.33	0.94	0.43	23.22	0.16	3.357078	0.152	39.68	0.20	4.297829	0.166	98	73	10
	1994	67.39	0.20	2.93	0.19	82.77	0.17	11.57065	0.167	150.16	0.16	14.50123	0.166	103	85	10
	1997	17.91	0.16	1.07	0.17	83.72	0.13	11.78592	0.121	101.63	0.13	12.85891	0.12	112	91	10
	1999	8.02	0.25	0.42	0.31	50.58	0.21	7.266118	0.189	58.60	0.21	7.689472	0.193	120	93	10
	2002	10.68	0.16	0.49	0.15	35.03	0.17	5.6948	0.165	45.71	0.14	6.188908	0.155	115	99	10
	2005	7.81	0.20	0.41	0.22	19.09	0.18	2.874266	0.17	26.90	0.16	3.283292	0.162	92	73	10
	2008	10.07	0.14	0.44	0.14	17.05	0.16	2.537086	0.168	27.11	0.13	2.97367	0.155	109	93	10
	2011	11.70	0.21	0.52	0.21	14.12	0.18	2.063531	0.192	25.82	0.16	2.586211	0.172	61	44	10

Table A10. Cont…

		Prerecruits (50-119 mm SL)				Large fishable (120+ mm SL)				All surfclams 50mm and above						
	Year	N / Tow	CV	KG / Tow	CV	N / Tow	CV	KG / Tow	CV	N / Tow	CV	KG / Tow	CV	N Tows	Pos. Tows	N Strata
LI	1982	0.03	1.00	0.002434	1	3.99	0.61	0.743364	0.606	4.03	0.61	0.745798	0.604	29	5	7
	1983	0.17	0.61	0.004333	0.613	0.41	0.72	0.057422	0.716	0.58	0.60	0.061755	0.688	29	4	7
	1984	0.56	0.30	0.020969	0.366	1.64	0.34	0.283652	0.353	2.20	0.22	0.304621	0.319	55	14	7
	1986	0.58	0.39	0.020603	0.403	1.72	0.61	0.305768	0.61	2.30	0.45	0.32637	0.567	29	8	7
	1989	2.24	0.87	0.088874	0.871	3.48	0.72	0.504931	0.726	5.72	0.78	0.593806	0.747	28	5	7
	1992	5.73	0.44	0.319383	0.476	2.54	0.33	0.295907	0.316	8.28	0.39	0.61529	0.373	28	10	7
	1994	4.23	0.17	0.211863	0.194	7.24	0.19	0.938826	0.208	11.48	0.17	1.150689	0.199	32	12	7
	1997	1.44	0.49	0.082004	0.533	4.17	0.64	0.604188	0.64	5.62	0.59	0.686193	0.622	28	6	7
	1999	1.61	0.64	0.048118	0.507	10.71	0.65	1.594682	0.607	12.32	0.65	1.6428	0.604	30	9	7
	2002	0.85	0.45	0.034689	0.439	1.94	0.67	0.331373	0.664	2.80	0.59	0.366062	0.636	29	8	7
	2005	1.42	0.34	0.062799	0.382	12.62	0.50	1.84611	0.479	14.04	0.47	1.908909	0.47	29	9	7
	2008	1.47	0.24	0.063645	0.236	3.52	0.24	0.534445	0.239	5.00	0.21	0.59809	0.23	60	22	7
	2011	4.57	0.26	0.156991	0.207	10.20	0.25	1.536774	0.253	14.76	0.21	1.693766	0.241	52	33	7
SNE	1982	2.58	0.29	0.131607	0.354	12.40	0.41	2.293756	0.418	14.99	0.33	2.425363	0.392	42	19	9
	1983	0.84	0.40	0.048743	0.435	7.88	0.39	1.712466	0.387	8.72	0.38	1.761209	0.385	54	24	9
	1984	0.81	0.36	0.042455	0.44	10.84	0.34	2.285845	0.336	11.65	0.34	2.3283	0.337	63	26	9
	1986	1.12	0.14	0.032305	0.252	4.12	0.68	0.872532	0.701	5.24	0.54	0.904837	0.678	25	11	8
	1989	1.18	0.43	0.051921	0.429	4.57	0.33	0.93215	0.332	5.75	0.31	0.984071	0.326	29	12	9
	1992	1.15	0.56	0.036055	0.482	2.49	0.58	0.558217	0.584	3.64	0.44	0.594272	0.55	31	9	9
	1994	1.26	0.52	0.077467	0.612	1.69	0.53	0.366591	0.549	2.96	0.45	0.444058	0.502	38	11	9
	1997	2.95	0.31	0.150038	0.362	12.28	0.30	2.555287	0.308	15.23	0.25	2.705325	0.298	34	15	9
	1999	2.60	0.42	0.102415	0.454	4.30	0.66	1.009042	0.663	6.90	0.45	1.111458	0.604	34	16	9
	2002	1.01	0.69	0.066557	0.719	3.85	0.27	0.825208	0.221	4.86	0.31	0.891765	0.229	24	9	8
	2005	1.33	0.08	0.052673	0.083	1.62	0.24	0.402845	0.241	2.95	0.14	0.455517	0.215	35	14	9

	2008	1.46	0.10	0.062659	0.126	5.01	0.63	1.03101	0.582	5.37	0.47	0.866775	0.545	32	11	9
	2011	1.35	0.09	0.051196	0.088	1.97	0.29	0.437128	0.278	3.07	0.18	0.434453	0.249	45	13	9
GBK	1986	20.00	0.79	0.783168	0.776	4.97	0.52	0.822095	0.549	24.97	0.68	1.605262	0.527	44	20	14
	1989	5.21	0.34	0.329709	0.425	24.86	0.73	3.523909	0.732	30.07	0.66	3.853617	0.704	75	37	14
	1992	15.54	0.40	0.800933	0.457	7.89	0.33	1.125339	0.342	23.43	0.33	1.926272	0.32	66	43	14
	1994	30.01	0.33	1.83765	0.347	45.84	0.39	6.734682	0.414	75.85	0.33	8.572331	0.375	70	47	14
	1997	58.55	0.31	3.402449	0.334	23.52	0.25	3.150657	0.245	82.07	0.28	6.553106	0.26	65	45	14
	1999	24.01	0.41	1.558739	0.416	29.59	0.31	3.945581	0.311	53.60	0.35	5.50432	0.337	59	34	14
	2002	22.09	0.52	1.358712	0.551	27.05	0.43	3.811007	0.417	49.15	0.46	5.169719	0.439	43	23	11
	2008	7.21	0.28	0.478127	0.335	33.02	0.25	4.605182	0.246	39.23	0.21	4.942882	0.224	45	29	14
	2011	7.62	0.21	0.513838	0.243	30.53	0.25	4.718915	0.246	43.79	0.24	6.109591	0.243	91	52	14

Table A11. Patch model results and approximate 95% confidence intervals for all surfclam depletion experiments conducted in 2011. The model for SC11-04 did not converge on a solution so no delta method confidence intervals are available.

Experiment	Tows	Density	CI	Efficiency	CI	Dispersion	CI
SC11-02	20	0.231	(0.14,0.25)	0.738	(0.53,0.90)	5.878	(2.95,10.65)
SC11-02S	18	0.184	(0.19,0.29)	0.556	(0.35,0.71)	4.904	(2.4,9.0)
SC11-03	15	0.416	(0.29,0.85)	0.571	(0.23,0.90)	4.156	(1.85,8.05)
SC11-04	17	0.163	NA	1	NA	6.438	NA

Table A12. F/V and R/V shell height composition data used to estimate NEFSC clam survey dredge selectivity for surfclams. Numbers of positive stations (e.g. R/V n positive stations) give the number of stations at which surfclams of each shell length group were captured. For example, "F/V lined dredge N positive stations" = 10 for the 20-29 mm SL group because individuals in the 20-29 mm size group were observed in F/V selectivity tows at 10 sites.

SL group	F/V lined dredge N	F/V unlined dredge N	R/V N	F/V lined dredge N positive stations	F/V unlined dredge N positive stations	R/V N positive stations
20-29	21	3	2	10	1	2
30-39	147	6	5	19	2	5
40-49	327	8	13	20	1	5
50-59	237	18	15	17	1	6
60-69	217	8	45	20	2	10
70-79	218	9	84	20	2	16
80-89	282	68	90	18	8	17
90-99	269	439	100	17	15	15
100-109	235	765	106	18	16	19
110-119	242	949	129	17	21	19
120-129	275	1256	132	18	21	20
130-139	227	1182	115	21	21	21
140-149	184	895	121	20	20	19
150-159	200	883	153	18	20	17
160-169	193	721	98	15	16	11
170-179	96	310	45	10	15	10
180-189	17	39	2	5	9	4
190-199	0	3	0	0	0	0

Table A13. Numbers of surfclams in survey dredge selectivity experiments by length bin and station (2011). For example, "3:8" means that 3 surfclams of a particular length at a particular station were measured in catches by the *R/V Delaware II* and 8 surfclams were measured in catches by the *F/V Pursuit*.

SL bin	Sta 7	Sta 23	Sta 28	Sta 34	Sta 43	Sta 49	Sta 50	Sta 51	Sta 52	Sta 53	Sta 56
6	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0
16	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:1	0:0	0:0	0:0
26	0:1	0:0	0:0	0:0	0:1	0:1	0:0	0:2	0:0	0:5	0:2
36	0:2	0:2	0:1	0:2	2:7	0:8	0:1	0:8	0:0	1:7	0:8
46	0:1	0:3	0:4	0:5	0:8	0:8	0:0	0:12	0:0	1:5	0:1
56	0:2	0:4	0:2	0:8	1:9	0:12	0:0	0:5	0:1	1:12	0:0
66	0:1	0:1	1:1	0:2	1:10	1:9	1:1	0:3	0:0	0:6	0:3
76	2:3	0:0	0:1	0:7	2:2	4:4	2:0	1:7	2:0	2:5	2:5
86	2:1	0:0	0:0	2:5	0:1	0:3	2:2	1:2	1:1	3:5	0:1
96	1:1	4:1	0:0	0:3	2:2	0:2	1:1	1:4	1:1	0:1	1:4
106	3:2	2:1	1:0	3:3	3:2	3:3	1:0	5:3	1:1	3:5	1:3
116	2:2	3:1	3:0	2:5	2:3	3:0	1:0	4:6	0:0	4:2	1:1
126	9:1	4:3	3:0	3:8	1:3	5:4	2:1	8:8	1:0	1:3	2:1
136	10:6	4:2	6:3	10:10	4:6	6:9	3:1	5:9	2:3	5:8	2:2
146	11:8	4:4	6:7	3:8	5:5	7:9	3:3	3:6	0:3	5:8	4:2
156	9:7	7:4	8:5	7:8	6:4	8:10	1:8	9:9	3:4	6:10	9:4
166	6:7	2:0	8:2	5:9	3:4	6:9	2:3	4:6	1:7	5:9	9:9
176	2:1	0:0	4:0	2:7	2:3	6:3	0:0	0:1	0:2	4:6	6:8
186	0:0	0:0	0:0	0:4	0:1	0:0	0:0	0:0	0:0	0:1	0:1

SL bin	Sta 141	Sta 156	Sta 167	Sta 234	Sta 236	Sta 239	Sta 240	Sta 247	Sta 255	Sta 279
6	0:0	0:1	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0
16	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0
26	1:6	0:1	0:2	0:0	0:1	0:0	1:1	0:2	0:1	0:1
36	1:9	2:13	0:3	1:5	0:2	0:2	0:13	0:1	0:12	0:4
46	5:10	1:15	0:3	1:9	1:12	0:1	1:11	0:0	0:6	0:3
56	6:9	3:11	0:2	0:7	1:3	0:2	1:0	0:3	0:8	0:9
66	9:12	7:12	1:3	1:7	0:3	0:9	3:5	1:8	6:8	0:4
76	8:12	6:12	2:2	1:7	0:4	2:7	6:11	2:7	9:9	2:9
86	10:11	8:10	1:2	8:10	1:1	6:11	7:11	3:9	10:11	1:9
96	10:8	8:12	3:1	4:10	0:0	7:11	4:10	3:9	9:11	0:5
106	11:9	6:12	3:2	5:10	1:1	5:10	5:9	2:6	6:9	0:2
116	12:11	6:12	4:3	4:10	3:0	7:9	3:9	5:9	12:10	0:5
126	9:10	5:12	3:1	2:9	0:1	7:11	3:7	4:8	10:8	1:4
136	3:4	3:5	2:2	2:8	4:1	5:9	2:9	8:10	5:3	5:4
146	2:2	0:3	3:2	1:8	3:1	6:8	1:4	5:6	1:2	0:4
156	0:0	1:0	0:0	0:3	1:1	0:4	2:1	4:6	0:0	0:6
166	0:0	0:0	0:0	0:2	0:3	0:0	0:0	0:2	0:0	0:4
176	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:1
186	0:0	0:1	0:0	0:0	0:0	0:0	0:0	0:0	0:0	0:0

Table A14. Estimated model parameters and (standard errors) for a selection of competing models predicting clam meat weight from shell length. Region effects are highlighted with colors corresponding to the row of the model they were estimated in.

Formula	Intercept	Length	Depth	Density	Region	AIC	BIC
MW ~ Len+(1|Sta)	-8.6041 (0.00941)	2.7249 (0.01431)				4911	4928
MW ~ Len+Dpth+(1|Sta)	-8.3705 (0.00934)	2.7227 (0.01433)	-0.0644 (0.0263)			4908	4930
MW ~ Len+(Len+1|Sta)	-8.6406 (0.0097)	2.7336 (0.02425)				4715	4742
MW ~ Len+Dpth+(Len+1|Sta)	-8.6236 (0.00966)	2.73 (0.02423)	-0.0614 (0.02721)			4712	4745
MW ~ Len+Reg+(Len+1|Sta)	-8.6383 (0.0174)	2.7276 (0.0245)			a	4695	4756
MW ~ Len+Dens+(Len+1|Sta)	-8.6347 (0.01001)	2.7363 (0.02445)	-0.00572 (0.00688)			4716	4749
MW ~ Len+(Len+1|Sta)+(Len+1|Yr)	-8.611 (0.0244)	2.7277 (0.04988)				4706	4750
MW ~ Len+Dpth+(Len+1|Sta)+(Len+1|Yr)	-8.3439 (0.02602)	2.7237 (0.04939)	-0.0714 (0.02675)			4701	4750
MW ~ Len+Reg+(Len+1|Sta)	-8.6383 (0.0174)	2.7276 (0.0245)			b	4695	4756
MW ~ Len+Dpth+Reg+(Len+1|Sta)	-7.976 (0.01687)	2.7175 (0.02426)	-0.1743 (0.03104)		c	4667	4734
MW ~ Len+Dpth+Reg+(Len+1|Sta)+(Len+1|Yr)	***-7.8622 (0.03454)***	***2.7061 (0.05402)***	***-0.1925 (0.02999)***		***d***	***4645***	***4728***
MW ~ Len+Dpth+Dens+Reg+(Len+1|Sta)+(Len+1|Yr)	-7.8391 (0.03551)	2.71 (0.05461)	-0.1951 (0.02983)	-0.0661 (0.06804)	e	4644	4732

Region	a	b	c	***d***	e
SVA	0.044 (0.07141)	0.044 (0.07141)	0.0129 (0.07043)	***-0.06 (0.06786)***	0.1714 (0.04491)
DMV	0	0	0	***0***	0
NJ	0.0162 (0.02251)	0.0162 (0.02251)	-0.00407 (0.02194)	***0.00247 (0.02111)***	-0.0824 (0.0308)
LI	-0.0219 (0.0307)	-0.0219 (0.0307)	-0.0889 (0.03172)	***-0.0816 (0.03101)***	0.2049 (0.03058)

SNE	0.1869 (0.04799)	0.1869 (0.04799)	0.1651 (0.04597)	***0.1808 (0.04497)***	-0.2668 (0.31418)
GBK	0.1141 (0.03001)	0.1141 (0.03001)	0.1792 (0.03096)	***0.2009 (0.03072)***	-0.0104 (0.0063)
OTH	-0.261 (0.32725)	-0.261 (0.32725)	-0.1631 (0.32651)	***-0.246 (0.31299)***	0.00636 (0.02111)

Table A15. Number of age samples by region and survey year.

Year	SVA	DMV	NJ	LI	SNE	GBK
1982	5	796	927	40	123	4
1983	142	422	934	6	369	0
1984	0	0	0	0	0	643
1986	64	748	1216	45	71	413
1989	60	102	566	53	42	86
1992	11	134	257	47	54	311
1994	0	299	476	0	0	0
1997	0	626	227	0	0	50
1999	0	510	496	22	50	178
2002	29	327	779	31	20	54
2005	17	322	523	21	6	0
2008	0	138	459	99	39	105
2011	26	122	144	72	17	82

Table A16. Growth curve (Von Bertalanffy) parameter estimates and standard errors for each region, by year.

Region	Year	n	L_{max}	L_{max} se	K	K se	t_0	t_0 se
DMV	1978	199	163.562	1.820	0.319	0.017	-0.010	0.096
DMV	1980	391	166.575	1.289	0.340	0.020	1.246	0.150
DMV	1981	446	173.336	1.855	0.248	0.014	0.451	0.154
DMV	1982	801	175.458	1.641	0.205	0.008	0.114	0.129
DMV	1983	564	176.522	2.512	0.214	0.013	0.113	0.190
DMV	1986	812	183.819	3.002	0.135	0.010	-1.204	0.366
DMV	1989	162	141.828	2.541	0.327	0.045	0.596	0.316
DMV	1992	145	172.122	6.760	0.161	0.025	-0.829	0.473
DMV	1994	299	149.550	1.661	0.343	0.022	1.437	0.134
DMV	1997	626	151.399	3.251	0.148	0.014	-1.472	0.395
DMV	1999	510	136.421	1.924	0.238	0.027	-0.314	0.482
DMV	2002	356	156.831	4.395	0.168	0.021	-1.223	0.434
DMV	2005	339	150.595	2.750	0.161	0.012	-0.735	0.235
DMV	2008	228	158.314	2.583	0.201	0.014	-0.607	0.197
DMV	2011	149	120.448	3.027	0.399	0.051	0.301	0.225
NJ	1978	289	163.504	2.858	0.313	0.025	0.207	0.147
NJ	1980	452	171.610	1.564	0.286	0.015	0.825	0.139
NJ	1981	641	170.430	1.330	0.316	0.013	0.703	0.094
NJ	1982	927	173.358	1.431	0.264	0.009	0.256	0.087
NJ	1983	934	176.348	1.733	0.244	0.010	0.267	0.109
NJ	1986	1216	175.558	1.866	0.177	0.008	-0.465	0.174
NJ	1989	566	162.936	2.012	0.238	0.015	0.585	0.183
NJ	1992	257	166.971	4.115	0.187	0.023	-0.422	0.432
NJ	1994	476	159.587	2.181	0.197	0.017	-0.580	0.356
NJ	1997	227	165.551	2.053	0.212	0.018	-0.046	0.291
NJ	1999	496	160.889	1.379	0.264	0.015	0.235	0.172
NJ	2002	779	163.876	1.728	0.209	0.015	-0.838	0.279
NJ	2005	523	164.111	2.418	0.150	0.013	-1.211	0.455
NJ	2008	807	158.901	2.251	0.152	0.011	-1.458	0.320
NJ	2011	145	154.582	3.475	0.216	0.031	-0.367	0.555
LI	1980	29	159.445	2.372	0.365	0.055	0.451	0.396
LI	1981	27	171.114	17.901	0.108	0.065	-5.719	4.260
LI	1982	40	156.713	1.856	0.800	0.213	2.815	0.198
LI	1986	45	165.899	3.402	0.222	0.039	0.023	0.695
LI	1989	53	163.122	3.557	0.259	0.034	0.529	0.394
LI	1992	47	155.779	3.029	0.307	0.036	0.008	0.314
LI	1999	22	167.863	4.719	0.302	0.044	0.550	0.283
LI	2002	31	174.942	8.130	0.250	0.059	0.313	0.594
LI	2005	21	160.095	7.630	0.210	0.070	-0.598	1.226
LI	2008	254	150.733	2.409	0.409	0.038	0.830	0.182
LI	2011	73	168.560	5.403	0.196	0.049	-0.784	1.258
SNE	1980	61	177.066	6.484	0.111	0.038	-7.483	3.807
SNE	1981	38	162.605	3.761	0.444	0.088	1.335	0.311
SNE	1982	123	160.352	2.398	0.222	0.025	0.642	0.378
SNE	1983	369	167.890	1.656	0.265	0.023	-0.209	0.350
SNE	1986	71	163.625	2.624	0.316	0.038	1.571	0.258
SNE	1989	42	171.995	5.179	0.422	0.079	2.009	0.350
SNE	1992	54	162.448	2.304	0.203	0.024	0.586	0.317

SNE	1999	50	174.800	6.337	0.210	0.041	-0.084	0.560
SNE	2002	20	162.292	5.311	0.452	0.118	1.539	0.525
SNE	2008	103	171.954	2.818	0.172	0.023	-1.036	0.677
SNE	2011	18	168.488	23.305	0.058	0.267	-37.007	193.965
GBK	1984	643	146.693	3.221	0.266	0.022	0.871	0.153
GBK	1986	413	148.950	3.236	0.225	0.019	0.267	0.175
GBK	1989	86	152.814	5.196	0.197	0.040	-0.250	0.765
GBK	1992	311	148.733	2.815	0.270	0.020	1.085	0.155
GBK	1997	50	138.772	7.371	0.194	0.045	-0.007	0.683
GBK	1999	178	145.613	3.129	0.355	0.033	0.581	0.160
GBK	2002	54	143.216	4.762	0.427	0.095	2.136	0.416
GBK	2008	315	147.423	2.587	0.204	0.023	-0.654	0.387
GBK	2011	83	146.346	2.053	0.486	0.189	2.249	1.109

Table A17. Points made to support splitting the Atlantic surfclams into two stocks with counterpoints. The status quo is a single stock and the alternative is two stocks with the break southwest of Georges Bank. Under this option, the Georges Bank (GBK) stock in the north would be separated from the South Virginia/ North Carolina to Southern New England (SVASNE) stock in the south. Points made to support maintaining the status quo and counterpoints are listed in Table A18.

Pro	Con	References
Spatial Patterns in Biological and Other Characteristics		
Growth curves and shell length-meat weight differ markedly between GBK and the southern region.	The differences are clinal or continuous and the split could be made elsewhere or not at all.	Table Table A14, Table A16, Figure A57, A58-62; Kim and Powell (2004); Marzec, et al. (2006); Weinberg (2005)
Post-settlement survival has decreased in the south but not on GBK.	Southern and northern portions of a large stock should respond differently to environmental change. The differences are clinal or concentrated in shallow water south of New Jersey and the split could be made elsewhere or not at all.	NEFSC 2010
Georges Bank tends to retain larvae spawned there due to a persistent gyre current. Published larval drift models for scallops show substantial movement of larvae from GBK to the south, but none from the south to GBK. A detailed unpublished surfclam larval drift presented to the Working Group indicates no movement of larvae from GBK to Southern New England and other southern areas occurs or *vice-versa* assuming no daily mortality during the assumed 35 day larval lifetime observed in culture (X. Zhang and D. Haidvogel, IMCS, Rutgers).	Larval drift models are not definitive and do not cover the whole time period of interest or all possible oceanographic conditions when substantial interchange may occur, particularly between GBK and Southern New England which is directly to the south. In certain circumstances, up to 10% of GBK larvae would reach Southern New England and these larvae would be 'unsuccessful' in the model, but near a reasonable size for metamorphosis in a biological sense.	Miller et al 1998; Werner et al 1993; Gilbert et al 2010; Tian et al 2009; Table A19
Georges Bank and MAB surfclam habitats are entirely within different and well recognized eco-regions.		Fogarty et al. (2011)

The split south of GBK crosses an area that separates the two major concentrations of the resource in the south (off New Jersey) and on GBK.	The split could be made elsewhere or not at all.	Appendix A7
Population Dynamics		
Surfclams in GBK and south resemble two independent populations based on abundance, recruitment and life history trends.	The northern and southern portions of SVASNE differ as well, why not identify three stocks?	POPULATION DYNAMICS (Figures A26, A27, A74, A75, A77 and A78)
Strong year classes occur independently and more often in the south and often over wide areas within the region.	Recruitment patterns are regional and the split could be made elsewhere or not at all.	Fig A67
Fishery Patterns		
The split south of GBK crosses an area of relatively low fishing activity and catch.		See Table A3, Figures A3,A4, and A8
Practical		
The new cooperative survey cannot sample the whole resource in one year but can be extended to include all of the SVASNE area.	Does not mean the split has to be made at GBK. Spatially explicit assessment models could be developed to handle areas incompletely sampled in annual surveys.	
Including GBK in a whole stock assessment model means that certain survey years cannot be included because GBK was not sampled in all years.	Areas can modeled separately but managed together, with results combined.	
Previous reviews of the surfclam assessment have been critical of the current stock definition.	Restoration of fishing on GBK invalidates some of these previous criticisms.	
The proposed boundary is along lines historically used to assess the stock and to collect survey data.	Historical use and best practice are not necessarily the same.	
Utility of Biological Reference Points		
”Average” biological reference points for two quasi-populations with different population dynamics do not result in MSY for either population unit, particularly when differences are as large as for GBK and the southern region.	The same argument can be made with respect to different portions of the southern area.	Hart, D. R. 2001. Can. J. Fish. Aquat. Sci. 58:2351–2358.

The surfclam stock could be removed entirely in the south or on GBK without triggering an overfishing or overfished status determination because biomass would remain > Bmsy/2 for the combined areas.	This scenario is unlikely to occur in either GBK or the southern area now that GBK is open to fishing	
Combining two quasi-populations with different population dynamics obscures the condition of both.	Assessments should contain information about both stock components and other important regions, regardless of stock definitions.	

Table A18. Points made to support maintaining the status-quo (single) stock definition for surfclams, with counterpoints. The status quo is a single stock and the alternative is two stocks with the break just southwest of Georges Bank.

Pro	Con	References
Split is a needless departure from historical precedent.	Historical precedent is not necessarily best practice particularly given biological and ecological changes.	
Scallops and ocean quahogs (other sessile bivalves) are managed as one stock	Many species (lobsters and relatively sessile fish such as goosefish and flounders) with interconnected meta-populations are managed as separate stocks. Precedent does not define best practice.	
Split made at the proposed point is not optimal - this aspect should be studied further before management action occurs	GBK is the most distinct region based on biological characteristics, oceanography, geography, larval dispersal and general ecological classifications. Additional divisions in the south can be made later if warranted.	
No genetic differences were found among samples of surfclams from Georges Bank to Virginia.	Lack of significant differences in genetic studies does not prove population homogeneity.	Weinberg, J.W. 2005. Mar. Biol. 146(4): 707-716
Recruitment in SNE may come from GBK at periods that have not been observed in models	There is insufficient age data for SNE to evaluate this hypothesis. However, the limited available data indicate that recruitment patterns differ between the major population centers (GBK in the north and New Jersey and Delmarva in the south).	TABLE A19

Table A19. Summary of unpublished results from surfclam larval drift simulation study courtesy of X. Zhang and D. Haidvogel (IMCS, Rutgers). Tables show the percentage of settlers released (columns) that settled successfully in each area (row) over 35 simulated days (the approximate larval stage duration) assuming no larval mortality. For example, of all the larvae released on Georges Bank, about 9.4% had settled on Georges Bank by the end of 35 days and none had settled elsewhere. Larvae were released from all major areas of surfclam habitat at five day intervals from May 21 to October 16, 2006-2009 (30 release dates) with results from all years and release dates summarized below. The size of each simulated larva was tracked in the model and larvae grew at a rate that depended on age, temperature and available food concentrations. Simulated larvae moved passively in horizontal directions but vertical movements were active at speeds dependent on size and water temperature. Larvae settled after they reached 260 μm, reached habitat with suitable water temperatures. They were considered dead if they had not settled in 35 days. The Regional Ocean Modeling System (ROMS) model used in simulations included forcing by rivers, tides, wind, radiation, air temperatures, humidity, etc. with a spatial resolution of 8 x 12 Km (120 x 160) grids.

		Release area (south on left, north on right)					
		Southern Virginia	DelMarva	New Jersey	Long Island	Southern New England	Georges Bank
		All years					
Settlement area (south bottom, north top)	Georges Bank	0	0	0	0	0	19.3556
	Southern New England	0	0	0	0.0167	0.3667	0
	Long Island	0	0	0.2130	37.1663	0.3333	0
	New Jersey	0	0.0683	78.7130	88.6910	0.1750	0
	DelMarva	1.9334	40.6430	80.9640	8.2167	0	0
	Southern Virginia	40.0997	85.8250	12.2463	0	0	0

Table A20. Structure of SS3 models used for surfclams in the southern and GBK areas.

Model aspect	Southern area	GBK area	Note
Natural mortality (M)	$0.15\ y^{-1}$		Constant for all ages and all years
Age bins	0-32+ y	0-30+ y	Few ages ≥ 30+ y
Population length bins	1, 2, … 19, 20 cm SL		
Time	1965-2011	1984-2011	South: starts first year with catch data and 17 y before first survey in 1982. North: starts first year with survey and catch data.
Seasons/ subareas/ morphs	None		
Commercial fleets	1		
Fishery size selectivity	Double normal (dome shaped), five parameters estimated and assumed constant over time	Double normal (logistic shaped) with left hand side from parameters estimated for south	Not estimable for GBK because of noisy and limited (2010-2011) commercial size data
Surveys	1 (2 variants)		NEFSC clam survey and minimum swept-area abundance based on clam survey data
Survey trend size selectivity	Field estimates		Double-normal selectivity curve fit externally to original GAM model estimates from field data (see parameter table)
Survey trend catchability	Estimated	Estimated	
Minimum swept area biomass size selectivity	Mirrors (same as) survey trend size selectivity		
Minimum swept area biomass catchability (capture efficiency)	Mean unbiased log scale parameter with normal prior	Fixed at estimate for southern area	Trend ignored in fitting model (weight 10-5) but catchability is calculated and compared to prior
Recruit model	Beverton-Holt with fixed steepness=0.95, estimate virgin recruitment and recruit variance		In effect, recruitments vary randomly around a constant mean estimated in the model and with a variance estimated in the model. Steepness is not important because biomass has never been low.
Recruit dev years	1965-2013	1969-2011	
Last early year with no bias adjustment	1919	1959	Adjusted based on preliminary fits
First year no full bias adjustment	1969	1974	
Last year full bias adjustment	2008	2006	
First recent year no bias adjustment	2012	2013	
Max bias adjustment	0.97	0.87	
Fishing mortality method	Hybrid method, 6 iterations (exact F)		Use Pope's approximation next time for speed if fishing mortality estimates remain low

Table A21. Parameters estimated internally and externally in SS3 models for surfclams in the southern and GBK regions. Numbers of parameters are summarized in the last rows.

Parameter	Southern area	SD (if estimated)	GBK area	CV (if estimated)	Note
M at ages 5 and 30 y	0.15	n/a	Same as south		
Length at age 4	10.245	0.045431	9.3017	0.10797	
Length at age 30	16.019	0.068704	14.846	0.11077	
Von Bertalanffy K	0.22379	n/a	0.253	n/a	
SD of size at ages 5 and 30 y	1.84	n/a	Same as south	n/a	
Shell length-meat weight					
Multiplier	0.000094	n/a	0.0001055	n/a	
Exponent	2.73325	n/a	2.73325	n/a	
Spawner-recruit					
Log virgin recruitment (R0)	14.893	0.13793	13.867	0.19071	
Steepness	0.95	n/a	Same as south		
Standard deviation	0.61803	0.064875	0.77469	0.086266	
Initial fishing mortality	0.016052	0.0024872	0	n/a	
Log catchability (capture efficiency) for swept area abundance	-1.1086	n/a	Same as south		This is a dummy parameter for comparison to capture efficiency prior
Size selectivity - fishery					
Peak	15.519	0.10544	15.4	n/a	GBK fishery selectivity parameters for left-hand side of double normal selectivity curve are fixed at same values as south. Parameters for right-hand side are fixed at values to ensure asymptotic pattern
Top	-9.7169	7.9249	10	n/a	
Asc-width	1.5949	0.076367	1.61	n/a	
Dsc-width	1.1254	0.1768	10	n/a	
Init	-999	n/a	-999	n/a	
Final	-999	n/a	-999	n/a	
Size selectivity - survey trend and swept-area abundance					
Peak	8.81897	n/a	Same as south		Estimated externally by fitting the double normal selectivity function to selectivity at size estimates from a mixed-effects GAM model.
Top	-0.64891	n/a			
Asc-width	2.23919	n/a			
Dsc-width	2.3557	n/a			
Init	-999	n/a			
Final	-0.817434	n/a			
N estimated parameters excluding recruit deviations	9		4		
N estimated recruit deviations	47		43		
Total N estimated parameters	56		47		

Table A22. Growth parameter estimates and goodness of fit from preliminary SS3 model runs for surfclams in the southern region. The lowest negative log likelihood values are shown in bold and the models are sorted from left (poorest fit) to right (best fit).

Statistic or growth parameter	Southern growth pars, normal prior on log q	Estimate Growth SD@Lmax	Estimate Lmax	Estimate K	Estimate Lmax and K	Estimate Growth SD@Lmin	Estimate both size@age SD	Estimate Lmin	Estimate Lmin and SD@Lmin	Estimate Lmin and Lmax	Estimate Lmin and K	Estimate all growth pars
NLL	1,248	1,245	1,241	1,235	1,234	1,216	1,205	1,167	1,166	1,156	1,128	1,122
Lmin	10.99	10.99	10.99	10.99	10.99	10.99	10.99	**11.79**	**11.76**	**11.81**	**11.91**	**11.97**
Lmax	16.19	16.19	**15.82**	16.19	**16.07**	16.19	16.19	16.19	16.19	**15.79**	16.19	**16.34**
K	0.22	0.22	0.22	**0.17**	**0.18**	0.22	0.22	0.22	0.22	0.22	**0.13**	**0.13**
SD min	1.84	1.84	1.84	1.84	1.84	**2.09**	**2.13**	1.84	**1.89**	1.84	1.84	**1.80**
SD max	1.84	**1.72**	1.84	1.84	1.84	1.84	**1.60**	1.84	1.84	1.84	1.84	**1.70**

Table A23. Goodness of fit for two preliminary SS3 models with likelihood weights on survey trend: lambda=1 and lambda=100. The lowest negative log likelihood values are shown in bold.

Label	Lambda = 1	Lambda = 100
Recruitment	**2.132**	10.016
Parm_priors	**0.051**	0.220
Survey trend	-3.768	**-7.582**
Lengths		
Fishery	**197.2**	199.4
Survey	**163.0**	176.7
Survey ages	**1,748**	1,873
Naked sum	**2,107**	2,251

SWAN Q=efficiency	0.19	0.27

B2011	1,020,610	611,096
B2011/B1999	0.49	0.36

Table A24. Data used in SS3 models for surfclams in the southern and GBK areas.

Data type	Southern area	GBK area	Note
Catches (mt meat weight)	1965-2011		Landings+discard+12% assumed incidental mortality
Historical catches (used to calculate initial biomass)	Average 1965-1969 = 12,802 mt		Landings+discard+12% assumed incidental mortality
Fishery length composition, 3-18 cm SL in 1 cm bins	N=30: 1982- 2011	N=2: 2010-2011	Southern area size data for 1982 and 1999 down-weighted (effective N=10).
Fishery age data	None		
Survey abundance data	N=13: 1982-1984, 1986, 1989, 1992, 1994, 1997, 1999, 2002, 2005, 2008, 2011	N=10: 1984, 1986, 1989, 1992, 1994,1997, 1999, 2002, 2008, 2011	Mean numbers per tow, without adjustments based on sensor data
Survey length data, 3-18 cm in cm bins	Same as survey abundance data		Southern area size data for 1984 downweighted (effective N=10) due to very large catch of surfclams almost entirely 7-8.9 cm SL
Survey age data (0-30+ y in 1 year age bins)	N=10: 1982-1983, 1986, 1989, 1992, 1999, 2002, 2005, 2008, 2011	N=9: 1984, 1986, 1989, 1992, 1997,1999, 2002, 2008, 2011	Age data were not collected from entire southern and GBK areas during some years
Minimum swept area abundance	N=6: 1997, 1999, 2002, 2005, 2008, 2011	N=5: 1997, 1999, 2002, 2008, 2011	Survey catches adjusted on a station-specific basis for tow distance using sensor data, total area adjusted for unsuitable habitat, bad tows discarded
Survey timing	0.51		Mean Julian date / 365
Likelihood weights	All 1.0 except 10^{-5} for minimum swept area abundance trend		
Initial growth parameters	External estimates		External estimates using all available age data for each region. L_{min} and L_{max} were estimated in final models (see parameter table) while other growth parameters were left at initial values.
Maturity	50% mature at age 2 1		Information about age specific fecundity limited
Age reader precision	Age data assumed unbiased with standard deviations for ageing errors increasing linearly from 0.144 y at age 0 y to 0.531 y at age 30 y		Based on between age reader comparison experiments and QA/QC experiments (ages read twice by same reader). All age data were collected by same reader.
Shell length - meat weight	External estimates		Estimates (ignoring depth effects) updated in this assessment

Table A25. Biomass (ages 6+ y or approximately 120+ mm SL, thousand mt), recruitment (10^9 age zero surfclams) and fully recruited fishing mortality (F) estimates from SS3 for the **southern area** with CVs.

Year	Biomass	CV.B	Recruitment	CV.R	F	CV.F
Virgin	1250	0.14	2937	0.14	NA	NA
1964	1160	0.14	2937	0.14	NA	NA
1965	1160	0.14	2133	0.22	0.02	0.16
1966	1157	0.14	2354	0.20	0.02	0.16
1967	1154	0.14	1767	0.21	0.02	0.16
1968	1155	0.14	2005	0.19	0.01	0.16
1969	1157	0.14	1515	0.20	0.01	0.15
1970	1162	0.14	1109	0.22	0.01	0.15
1971	1135	0.14	1109	0.21	0.03	0.15
1972	1101	0.14	1321	0.19	0.04	0.15
1973	1044	0.14	1958	0.18	0.05	0.16
1974	990	0.15	2319	0.17	0.06	0.16
1975	922	0.15	2917	0.17	0.04	0.16
1976	856	0.15	6987	0.16	0.04	0.16
1977	794	0.15	10658	0.15	0.04	0.17
1978	746	0.15	7661	0.16	0.03	0.17
1979	733	0.15	7911	0.15	0.03	0.17
1980	738	0.15	9529	0.15	0.04	0.17
1981	768	0.15	4859	0.16	0.05	0.17
1982	950	0.15	3995	0.16	0.04	0.17
1983	1277	0.15	4278	0.16	0.03	0.17
1984	1484	0.15	2822	0.18	0.03	0.17
1985	1684	0.15	2621	0.19	0.02	0.17
1986	1929	0.15	4001	0.18	0.02	0.17
1987	1974	0.15	3253	0.18	0.02	0.17
1988	1967	0.15	3094	0.19	0.02	0.17
1989	1956	0.15	3915	0.18	0.02	0.17
1990	1880	0.16	2607	0.19	0.02	0.17
1991	1789	0.16	3034	0.19	0.02	0.17
1992	1756	0.16	4698	0.18	0.02	0.17
1993	1696	0.16	3428	0.18	0.02	0.17
1994	1634	0.16	1712	0.19	0.02	0.17
1995	1608	0.16	1236	0.20	0.02	0.17
1996	1539	0.16	1672	0.19	0.02	0.17
1997	1490	0.16	1738	0.19	0.02	0.17
1998	1511	0.17	2998	0.19	0.02	0.17
1999	1488	0.17	2759	0.19	0.02	0.18
2000	1399	0.17	1465	0.20	0.02	0.18
2001	1294	0.17	552	0.24	0.03	0.18
2002	1207	0.17	849	0.22	0.03	0.18
2003	1128	0.18	851	0.23	0.04	0.18
2004	1104	0.18	1438	0.22	0.04	0.19
2005	1079	0.18	2240	0.21	0.03	0.19
2006	1013	0.18	2027	0.23	0.04	0.19
2007	912	0.19	1906	0.25	0.05	0.20
2008	827	0.19	1594	0.27	0.05	0.20
2009	750	0.19	2115	0.31	0.04	0.21
2010	706	0.20	3017	0.39	0.04	0.21
2011	703	0.20	1704	0.55	0.04	0.21

Table A26. Biomass (ages 7+ y or approximately 120+ mm SL, thousand mt), recruitment (10^9 age zero surfclams) and fully recruited fishing mortality (F) estimates from SS3 for the **northern (i.e., GBK) area** with CVs.

Year	Biomass	CV.B	Recruitment	CV.R	F	CV.F
1982	380	0.19	1053	0.19	0.00	0.00
1983	380	0.19	1053	0.19	0.00	0.00
1984	504	0.20	2056	0.24	0.01	0.20
1985	508	0.19	949	0.32	0.01	0.20
1986	522	0.19	1383	0.28	0.01	0.21
1987	523	0.19	1520	0.27	0.00	0.21
1988	532	0.18	1707	0.26	0.00	0.20
1989	521	0.19	1041	0.31	0.00	0.20
1990	518	0.19	1000	0.31	0.00	0.20
1991	541	0.19	750	0.35	0.00	0.00
1992	522	0.19	883	0.38	0.00	0.00
1993	520	0.16	3289	0.25	0.00	0.00
1994	522	0.16	3597	0.24	0.00	0.00
1995	532	0.18	1636	0.29	0.00	0.00
1996	517	0.17	1553	0.27	0.00	0.00
1997	500	0.17	1469	0.29	0.00	0.00
1998	475	0.17	1583	0.31	0.00	0.00
1999	456	0.18	849	0.39	0.00	0.00
2000	528	0.18	241	0.62	0.00	0.00
2001	610	0.18	354	0.54	0.00	0.00
2002	616	0.18	314	0.55	0.00	0.00
2003	616	0.18	234	0.51	0.00	0.00
2004	610	0.18	319	0.39	0.00	0.00
2005	608	0.18	356	0.33	0.00	0.00
2006	578	0.18	380	0.35	0.00	0.00
2007	526	0.18	300	0.43	0.00	0.00
2008	481	0.18	156	0.57	0.00	0.00
2009	437	0.18	171	0.58	0.00	0.19
2010	394	0.18	240	0.62	0.00	0.19
2011	357	0.18	385	0.69	0.01	0.19

Table A26B. Biomass (approximately 120+ mm SL, thousand mt), recruitment (10^9 age zero surfclams) and fully recruited fishing mortality (F) estimates from SS3 for the **whole stock** with CVs.

Year	Biomass	cv	Recruitment	cv	F	cv
1982	1331	0.12	5048	0.14		
1983	1657	0.12	5331	0.14		
1984	1987	0.12	4878	0.15	0.021	0.166
1985	2191	0.13	3570	0.16	0.019	0.164
1986	2451	0.13	5384	0.15	0.018	0.261
1987	2497	0.13	4773	0.15	0.016	0.261
1988	2500	0.13	4801	0.15	0.016	0.262
1989	2477	0.13	4956	0.16	0.015	0.262
1990	2398	0.13	3607	0.16	0.017	0.262
1991	2330	0.13	3783	0.17	0.015	0.262
1992	2278	0.13	5581	0.16	0.016	0.262
1993	2216	0.13	6717	0.15	0.016	0.165
1994	2156	0.13	5309	0.17	0.017	0.166
1995	2140	0.13	2872	0.19	0.015	0.167
1996	2055	0.13	3225	0.16	0.016	0.168
1997	1990	0.13	3207	0.17	0.015	0.169
1998	1986	0.13	4581	0.16	0.015	0.170
1999	1944	0.14	3608	0.17	0.017	0.171
2000	1927	0.13	1707	0.19	0.017	0.173
2001	1903	0.13	906	0.26	0.020	0.175
2002	1823	0.13	1163	0.22	0.022	0.177
2003	1744	0.13	1086	0.21	0.024	0.180
2004	1714	0.13	1758	0.19	0.024	0.184
2005	1687	0.13	2596	0.19	0.022	0.187
2006	1591	0.13	2407	0.20	0.025	0.190
2007	1439	0.14	2206	0.22	0.029	0.194
2008	1307	0.14	1749	0.26	0.028	0.198
2009	1187	0.14	2286	0.29	0.027	0.275
2010	1100	0.14	3257	0.37	0.025	0.277
2011	1060	0.14	2089	0.47	0.027	0.280

Table A27. Likelihood profile analysis for survey dredge efficiency, biomass, and biomass status (B2011/B1999) using the basecase SS3 model for surfclams in the southern area. Minimum likelihood values for each term are highlighted.

Label	Q=0.18	Q=0.26	Q=0.3	Q=0.33 (basecase)	Q=0.38	Q=0.44	Q=0.49
TOTAL	2036.0	2032.5	2031.7	**2031.5**	2032.0	2033.9	2036.1
Recruitment	3.479	3.035	**2.940**	2.948	3.124	3.791	4.728
Parm_priors	**0.057**	0.217	0.318	0.383	0.504	0.672	0.808
Parm_softbounds	0.003	0.003	0.003	0.003	0.003	0.003	**0.003**
Survey	-3.013	-3.385	-3.568	**-3.604**	-3.444	-2.738	-1.915
Lengths							
Fishery lengths	204.210	203.237	202.930	202.790	202.615	202.516	**202.515**
Survey lengths	151.100	149.685	149.213	148.976	148.614	148.219	**147.954**
Survey ages	1680.2	**1679.7**	1679.9	1680.1	1680.6	1681.4	1682.0

B2011	1,387,280	915,528	772,377	702,902	599,781	493,921	**428,446**
B2011/B1999	0.51	0.49	0.48	0.47	0.46	0.44	**0.42**

Table A28. Table comparing the biomass estimates from previous surfclam assessments. Note that in the current assessment animals greater than 120 mm are 6 and older in the southern area and 7 and older in the north, due to differing growth rates.

Year	2012	SAW 49 (NEFSC 2009)	SAW 44 (NEFSC 2007)	SAW 37 (NEFSC 2003)	SAW 30 (NEFSC 2000)	SAW 26 (NEFSC 1998)
Shell length (mm)	~120+ (age 6+ South, 7+ North)	120+	120+	120+ in NJ; 100+ elsewhere	120+ in NJ; 100+ elsewhere	All
Method	SS3	KLAMZ	KLAMZ	SWAB	KLAMZ	SWAB
Year	Biomass	Biomass	Biomass			
1981		831	1,020			
1982	1,331	862	1,036			
1983	1,657	889	1,059			
1984	1,987	916	1,083			
1985	2,191	935	1,141			
1986	2,451	954	1,225			
1987	2,497	973	1,271			
1988	2,500	988	1,290			
1989	2,477	1,003	1,289			
1990	2,398	1,021	1,285		1,200	
1991	2,330	1,029	1,283		1,200	
1992	2,278	1,045	1,290		1,200	
1993	2,216	1,059	1,476		1,200	
1994	2,156	1,070	1,613		1,200	
1995	2,140	1,082	1,709		1,200	
1996	2,055	1,088	1,780	1,146	1,200	1,113
1997	1,990	1,090	1,842		1,300	
1998	1,986	1,092	1,824	1,460	1,300	
1999	1,944	1,086	1,799			
2000	1,927	1,074	1,723			
2001	1,903	1,059	1,628	803		
2002	1,823	1,037	1,531			
2003	1,744	1,012	1,415			
2004	1,714	984	1,292			
2005	1,687	955				
2006	1,591	931				
2007	1,439	905				
2008	1,307					
2009	1,187					
2010	1,100					
2011	1,060					

Table A29. Whole stock biomass status estimates for 2011 with cv and approximate 95% confidence intervals.

	Biomass	cv	lci	uci
2011	1060	0.143	802	1401
Target	972	0.135	747	1235
Threshold	486	0.135	373	633

Table A30. Whole stock F status estimates for 2011 with cv and approximate 95% confidence intervals.

	F	cv	lci	uci
2011	0.027	0.271	0.016	0.045
Threshold	0.15			

Table A31 Southern area biomass status estimates for 2011 with cv and approximate 95% confidence intervals.

	Biomass	cv	lci	uci
2011	703	0.196	481	1028
Target	744	0.168	537	1032
Threshold	372	0.168	268	516

Table A32. Southern area F status estimates for 2011 with cv and approximate 95% confidence intervals.

	F	cv	lci	uci
2011	0.040	0.211	0.025	0.056
Threshold	0.15			

Table A33. Projected biomass and biomass status ($B/B_{threshold}$ where $B_{threshold}=B_{1999}/4$) during 2012-2021 for surflclams in the southern, GBK and combined areas.

Year	Southern area			GBK area			Southern + GBK		
	F=0.15 (M)	Status-quo catch	Quota	F=0.15 (M)	Status-quo catch	Quota	F=0.15 (M)	Status-quo catch	Quota
Biomass (mt)									
2011	704,366	704,366	704,366	370,217	370,217	370,217	1,074,583	1,074,583	1,074,583
2012	699,480	699,480	699,480	338,866	338,866	338,866	1,038,346	1,038,346	1,038,346
2013	690,839	690,839	690,839	308,580	308,580	308,580	999,419	999,419	999,419
2014	633,310	677,921	672,888	252,941	271,536	271,536	886,251	949,457	944,424
2015	604,667	686,541	676,966	208,410	238,833	238,833	813,077	925,374	915,799
2016	617,034	731,098	717,356	175,171	212,330	212,330	792,205	943,428	929,686
2017	585,090	725,516	708,212	154,269	194,626	194,626	739,359	920,142	902,838
2018	597,117	761,170	740,671	160,621	202,314	202,314	757,738	963,484	942,985
2019	614,769	800,317	777,001	172,120	214,381	214,381	786,889	1,014,698	991,382
2020	632,270	837,938	812,136	185,038	227,946	227,946	817,308	1,065,884	1,040,082
2021	648,414	873,215	845,220	197,790	241,864	241,864	846,204	1,115,079	1,087,084
Biomass / Bthreshold (Bthreshold=B1999/4)									
1999	1,513,100			506,882			2,019,982		
Bthreshold	378,275			126,721			504,996		
2011	1.86	1.86	1.86	2.92	2.92	2.92	2.13	2.13	2.13
2012	1.85	1.85	1.85	2.67	2.67	2.67	2.06	2.06	2.06
2013	1.83	1.83	1.83	2.44	2.44	2.44	1.98	1.98	1.98
2014	1.67	1.79	1.78	2.00	2.14	2.14	1.75	1.88	1.87
2015	1.60	1.81	1.79	1.64	1.88	1.88	1.61	1.83	1.81
2016	1.63	1.93	1.90	1.38	1.68	1.68	1.57	1.87	1.84
2017	1.55	1.92	1.87	1.22	1.54	1.54	1.46	1.82	1.79
2018	1.58	2.01	1.96	1.27	1.60	1.60	1.50	1.91	1.87
2019	1.63	2.12	2.05	1.36	1.69	1.69	1.56	2.01	1.96
2020	1.67	2.22	2.15	1.46	1.80	1.80	1.62	2.11	2.06
2021	1.71	2.31	2.23	1.56	1.91	1.91	1.68	2.21	2.15

Table A34. Projected landings (mt and bu) during 2012-2021 for surflclams in the southern, GBK and combined areas.

Year	Southern area			GBK area			Southern + GBK		
	F=0.15 (M)	Status-quo catch	Quota	F=0.15 (M)	Status-quo catch	Quota	F=0.15 (M)	Status-quo catch	Quota
	Landings (mt, catch - 12% incidental mortality)								
2011	16,089	16,089	16,089	2,127	2,127	2,127	18,216	18,216	18,216
2012	18,728	18,728	18,728	2,127	2,127	2,127	20,854	20,854	20,854
2013	60,767	13,145	18,504	28,352	7,710	7,710	89,119	20,854	26,213
2014	57,705	13,145	18,504	23,444	7,710	7,710	81,150	20,854	26,213
2015	55,609	13,145	18,504	19,570	7,710	7,710	75,178	20,854	26,213
2016	54,683	13,145	18,504	16,829	7,710	7,710	71,512	20,854	26,213
2017	54,690	13,145	18,504	15,235	7,710	7,710	69,925	20,854	26,213
2018	55,444	13,145	18,504	14,658	7,710	7,710	70,102	20,854	26,213
2019	56,660	13,145	18,504	14,827	7,710	7,710	71,488	20,854	26,213
2020	58,057	13,145	18,504	15,448	7,710	7,710	73,505	20,854	26,213
2021	59,431	13,145	18,504	16,279	7,710	7,710	75,710	20,854	26,213
Landings (bu, catch - 12% incidental mortality)									
2011	2,086,796	2,086,796	2,086,796	275,848	275,848	275,848	2,362,644	2,362,644	2,362,644
2012	2,429,011	2,429,011	2,429,011	275,848	275,848	275,848	2,704,859	2,704,859	2,704,859
2013	7,881,636	1,704,882	2,399,944	3,677,240	999,977	999,977	11,558,875	2,704,859	3,399,921
2014	7,484,494	1,704,882	2,399,944	3,040,787	999,977	999,977	10,525,280	2,704,859	3,399,921
2015	7,212,525	1,704,882	2,399,944	2,538,250	999,977	999,977	9,750,776	2,704,859	3,399,921
2016	7,092,540	1,704,882	2,399,944	2,182,694	999,977	999,977	9,275,234	2,704,859	3,399,921
2017	7,093,374	1,704,882	2,399,944	1,976,028	999,977	999,977	9,069,402	2,704,859	3,399,921
2018	7,191,136	1,704,882	2,399,944	1,901,184	999,977	999,977	9,092,320	2,704,859	3,399,921
2019	7,348,932	1,704,882	2,399,944	1,923,129	999,977	999,977	9,272,061	2,704,859	3,399,921
2020	7,530,109	1,704,882	2,399,944	2,003,590	999,977	999,977	9,533,699	2,704,859	3,399,921
2021	7,708,252	1,704,882	2,399,944	2,111,404	999,977	999,977	9,819,657	2,704,859	3,399,921

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Table A35. Projected fully recruited fishing mortality and exploitation rates (catch weight / biomass ages 6+) during 2012-2021 for surfclams in the southern, GBK and combined areas.

Year	Southern area			GBK area			Southern + GBK		
	F=0.15 (M)	Status-quo catch	Quota	F=0.15 (M)	Status-quo catch	Quota	F=0.15 (M)	Status-quo catch	Quota
	Fully recruited fishing mortality								
2011	0.037	0.037	0.037	0.009	0.009	0.009	0.028	0.028	0.028
2012	0.044	0.044	0.044	0.010	0.010	0.010	0.033	0.033	0.033
2013	0.150	0.031	0.044	0.150	0.039	0.039	0.150	0.034	0.042
2014	0.150	0.031	0.044	0.150	0.044	0.044	0.150	0.035	0.043
2015	0.150	0.031	0.044	0.150	0.050	0.050	0.150	0.035	0.044
2016	0.150	0.030	0.043	0.150	0.055	0.055	0.150	0.035	0.044
2017	0.151	0.029	0.042	0.150	0.059	0.059	0.150	0.035	0.044
2018	0.151	0.028	0.040	0.151	0.061	0.061	0.150	0.035	0.043
2019	0.151	0.026	0.038	0.151	0.060	0.060	0.150	0.034	0.042
2020	0.151	0.025	0.037	0.151	0.058	0.058	0.150	0.033	0.040
2021	0.151	0.024	0.035	0.151	0.056	0.056	0.150	0.032	0.039
Exploitation rate (catch/biomass)									
2011	0.026	0.026	0.026	0.006	0.006	0.006	0.019	0.019	0.019
2012	0.030	0.030	0.030	0.007	0.007	0.007	0.022	0.022	0.022
2013	0.099	0.021	0.030	0.103	0.028	0.028	0.100	0.023	0.029
2014	0.102	0.022	0.031	0.104	0.032	0.032	0.103	0.025	0.031
2015	0.103	0.021	0.031	0.105	0.036	0.036	0.104	0.025	0.032
2016	0.099	0.020	0.029	0.108	0.041	0.041	0.101	0.025	0.032
2017	0.105	0.020	0.029	0.111	0.044	0.044	0.106	0.025	0.033
2018	0.104	0.019	0.028	0.102	0.043	0.043	0.104	0.024	0.031
2019	0.103	0.018	0.027	0.096	0.040	0.040	0.102	0.023	0.030
2020	0.103	0.018	0.026	0.094	0.038	0.038	0.101	0.022	0.028
2021	0.103	0.017	0.025	0.092	0.036	0.036	0.100	0.021	0.027

Table A36. Cumulative probability of being in overfished status in any of the years 2013 – 2017, under a variety of catch scenarios.

Catch scenario	P[overfished][1]	P[overfishing][1]
Whole stock		
Status Quo	0.019	0.000
Quota	0.022	0.000
OFL (F = M) catch	0.123	0.990
Southern Area		
Status Quo	0.053	0.000
Quota	0.061	0.000
OFL (F = M) catch	0.162	0.990
Northern Area		
Status Quo	NA	0.000
Quota	NA	0.000
OFL (F = M) catch	NA	0.990

1 Probabilities are cumulative (2013 - 2017)

Table A37. Estimated catch at the OFL for the next five years by area.

Year	Mean	Median	CV
Whole stock			
2014	92324	90886	0.179
2015	85693	84191	0.189
2016	81658	80102	0.198
2017	79908	78326	0.202
2018	80124	78516	0.203
Southern area			
2014	66202	34622	0.223
2015	63969	62304	0.233
2016	62950	61221	0.239
2017	63027	61249	0.242
2018	63908	62117	0.243
Northern area			
2014	27302	26252	0.286
2015	22879	21915	0.3
2016	19721	18860	0.306
2017	17849	17056	0.308
2018	17180	16412	0.309

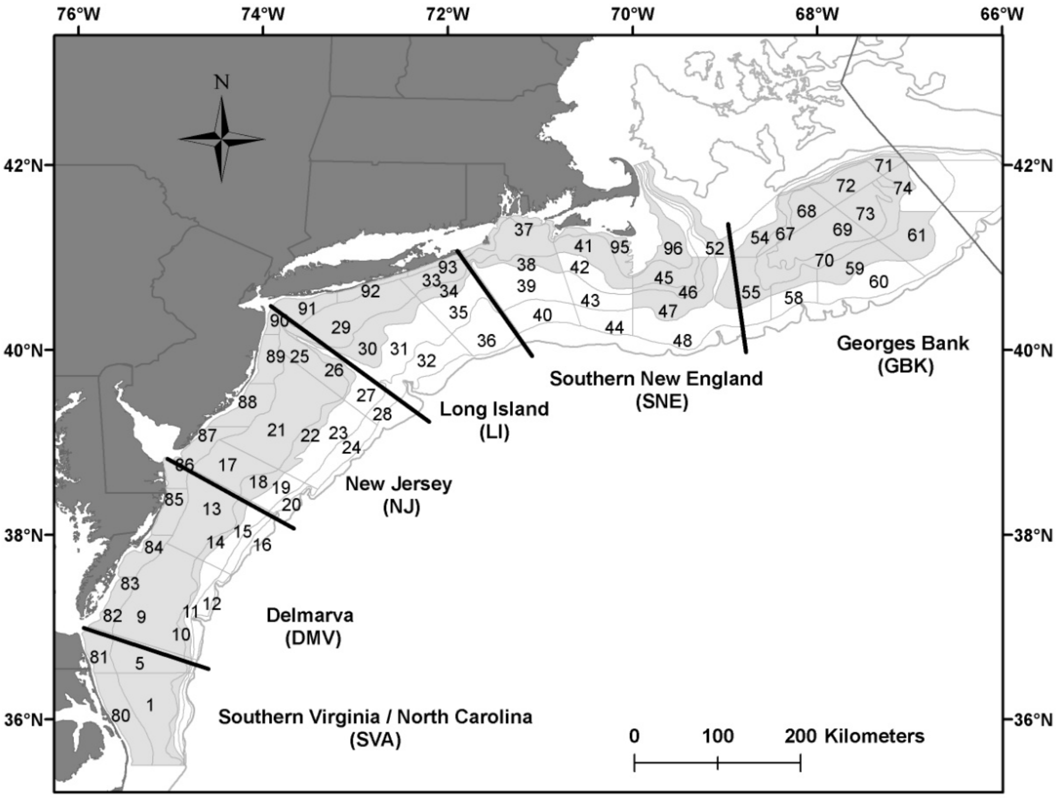

Figure A1. Surfclam stock assessment regions and NEFSC shellfish survey strata. The shaded strata are where surfclams are found.

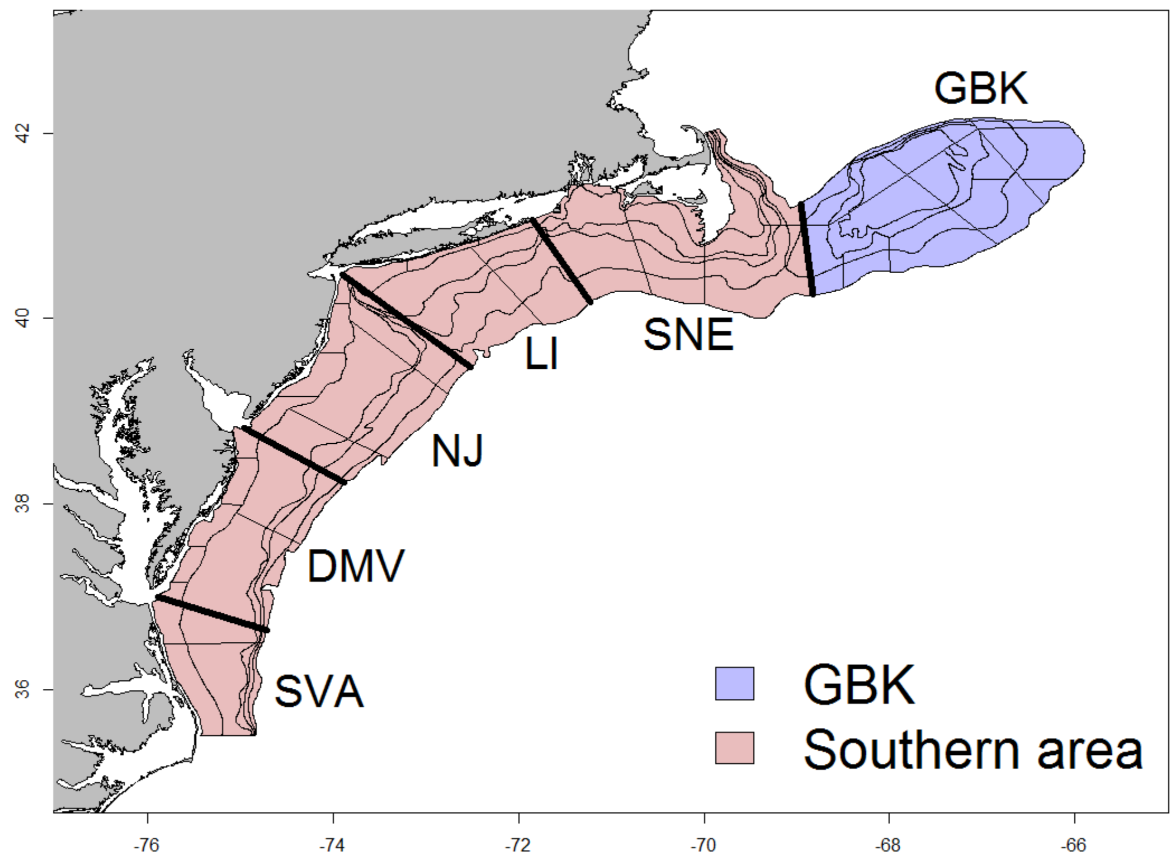

Figure A2. The surfclam regions divided into two areas.

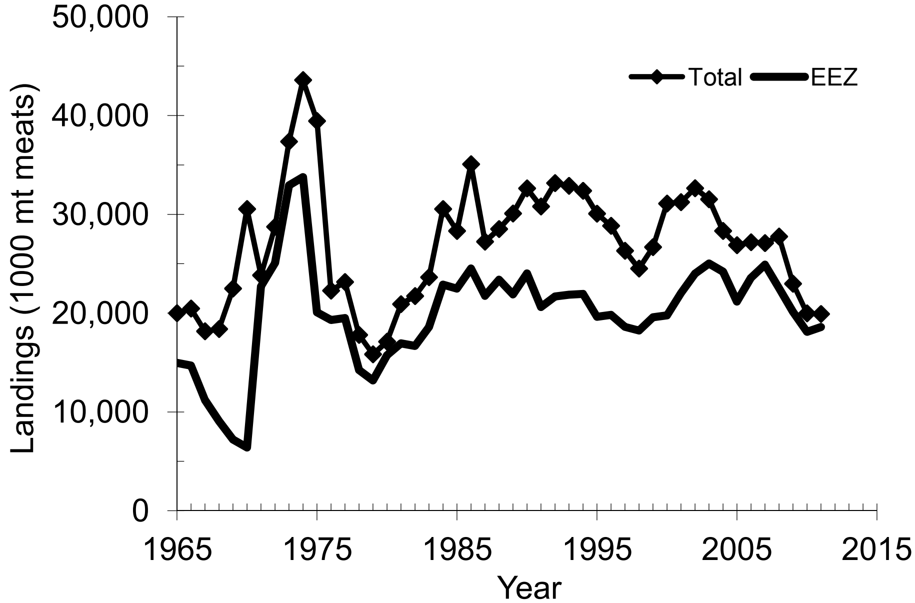

Figure A3. Surfclam landings (total and EEZ) during 1965-2011.

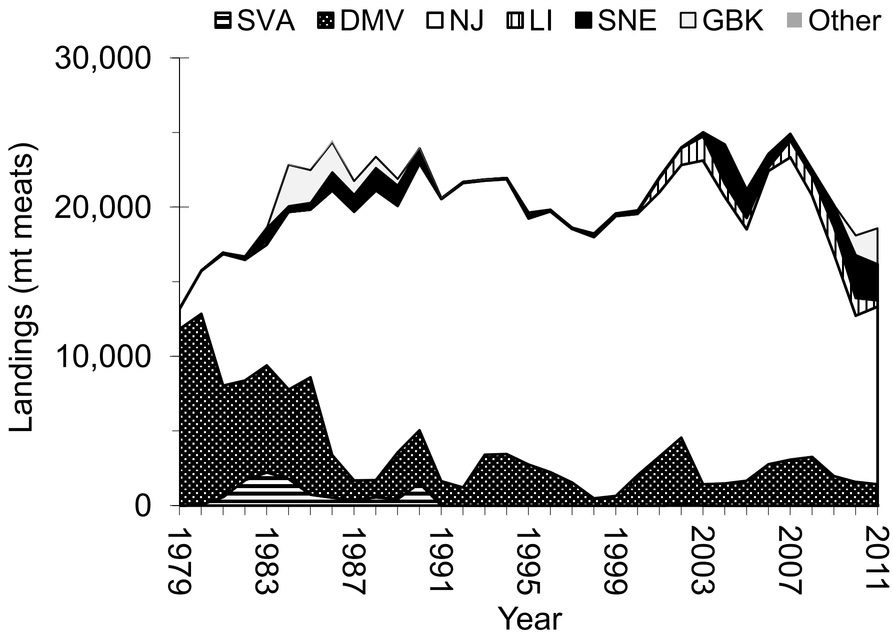

Figure A4. Surfclam landings from the US EEZ during 1979-2011, by stock assessment region.

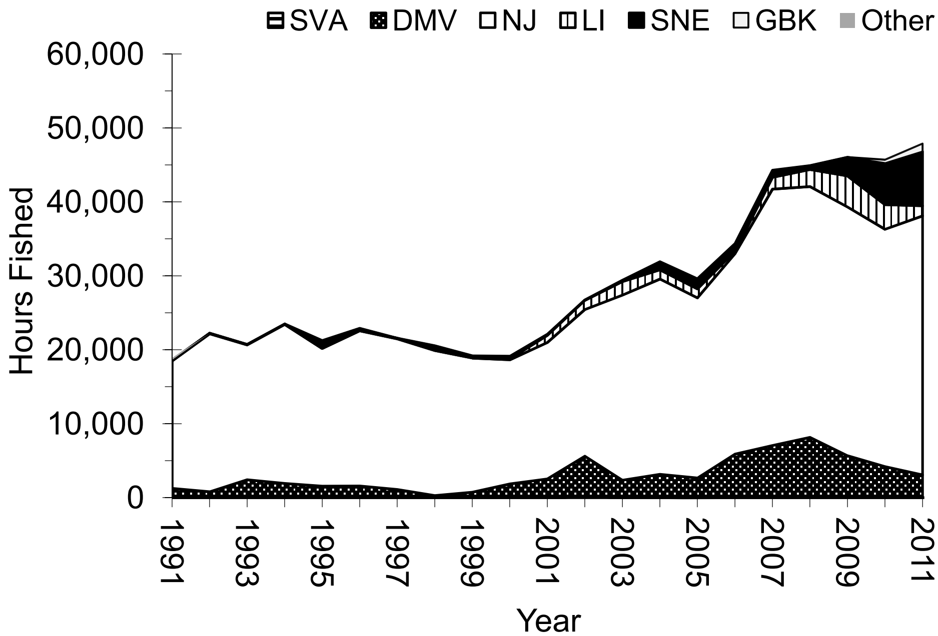

Figure A5. Surfclam hours fished from the US EEZ during 1991-2011, by stock assessment region.

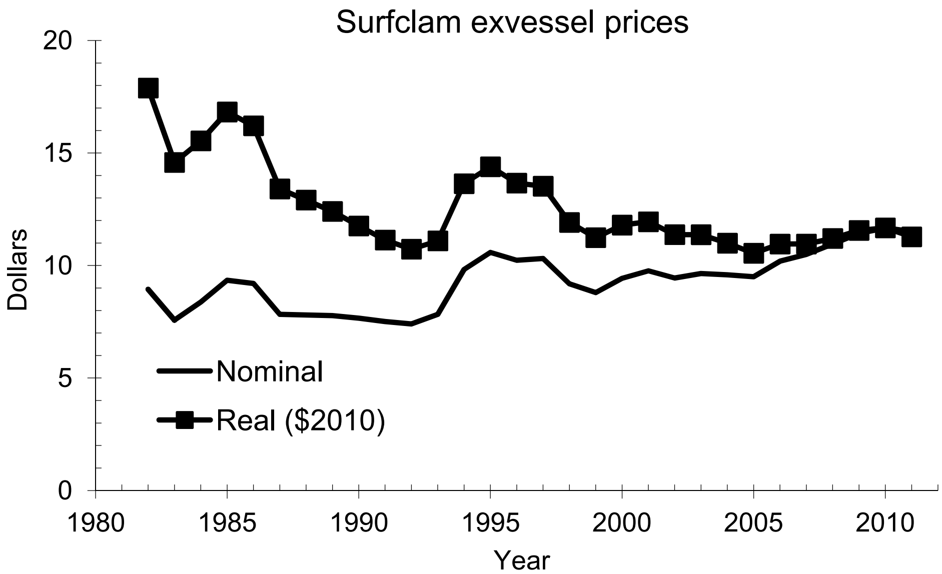

Figure A6. Nominal and 2010 dollar equivalent prices for surfclam 1981-2011.

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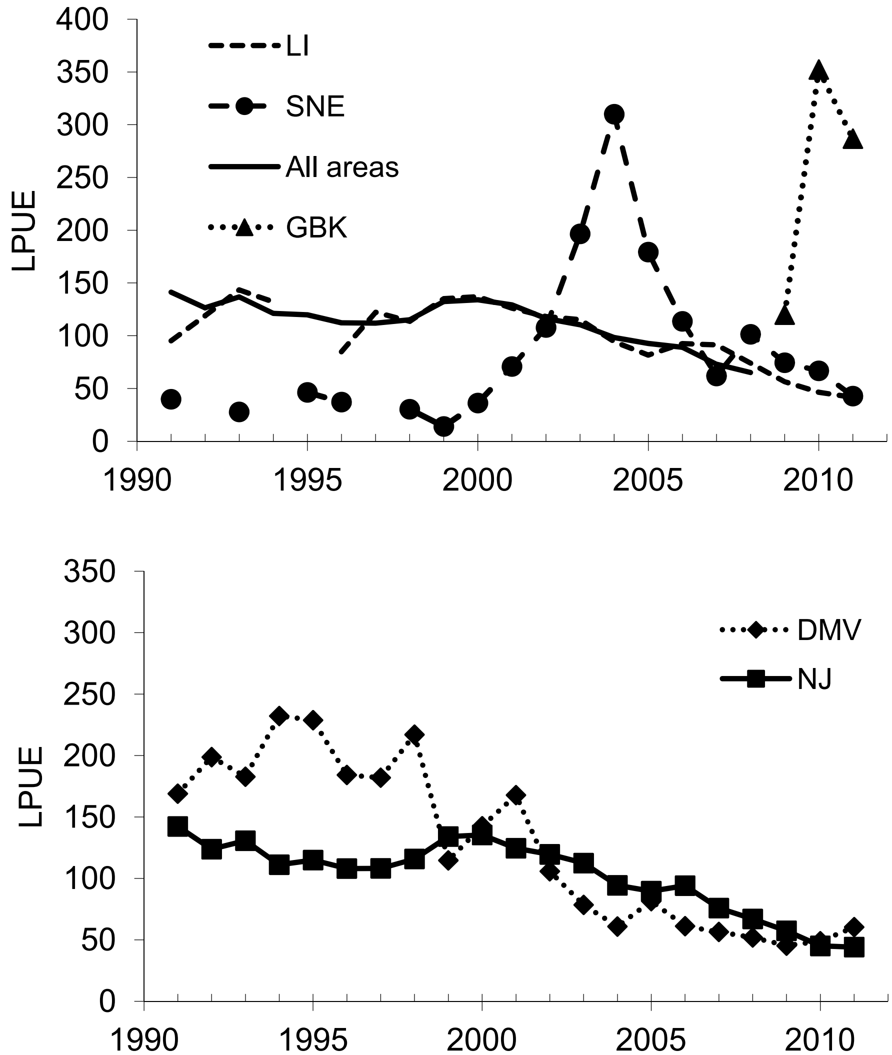


Figure A7. Nominal landings per unit effort (LPUE in bushels landed per hour fished) for surfclam, by region. LPUE is total landings in bushels divided by total fishing effort

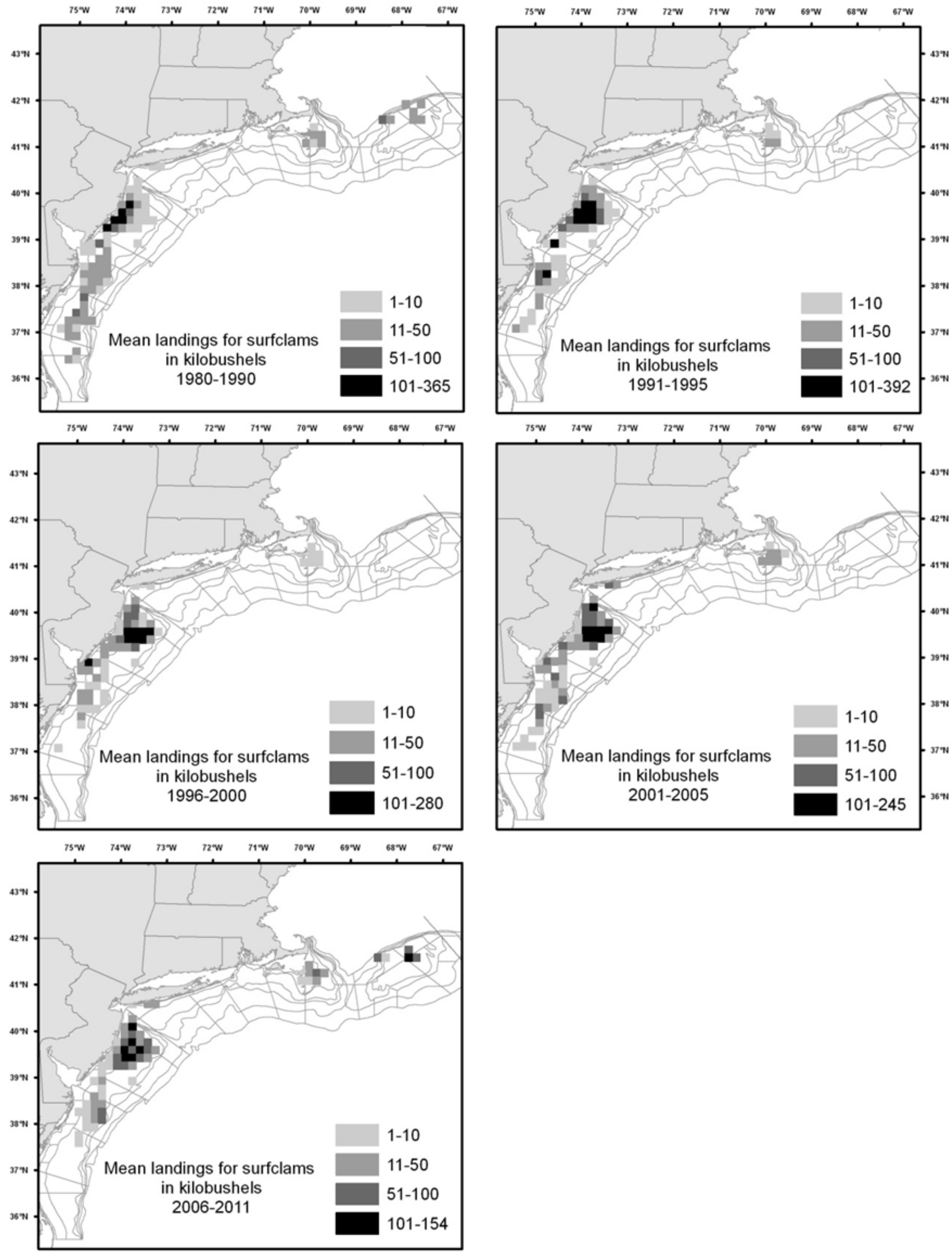


Figure A8. Average surfclams landings by ten-minute squares over time.

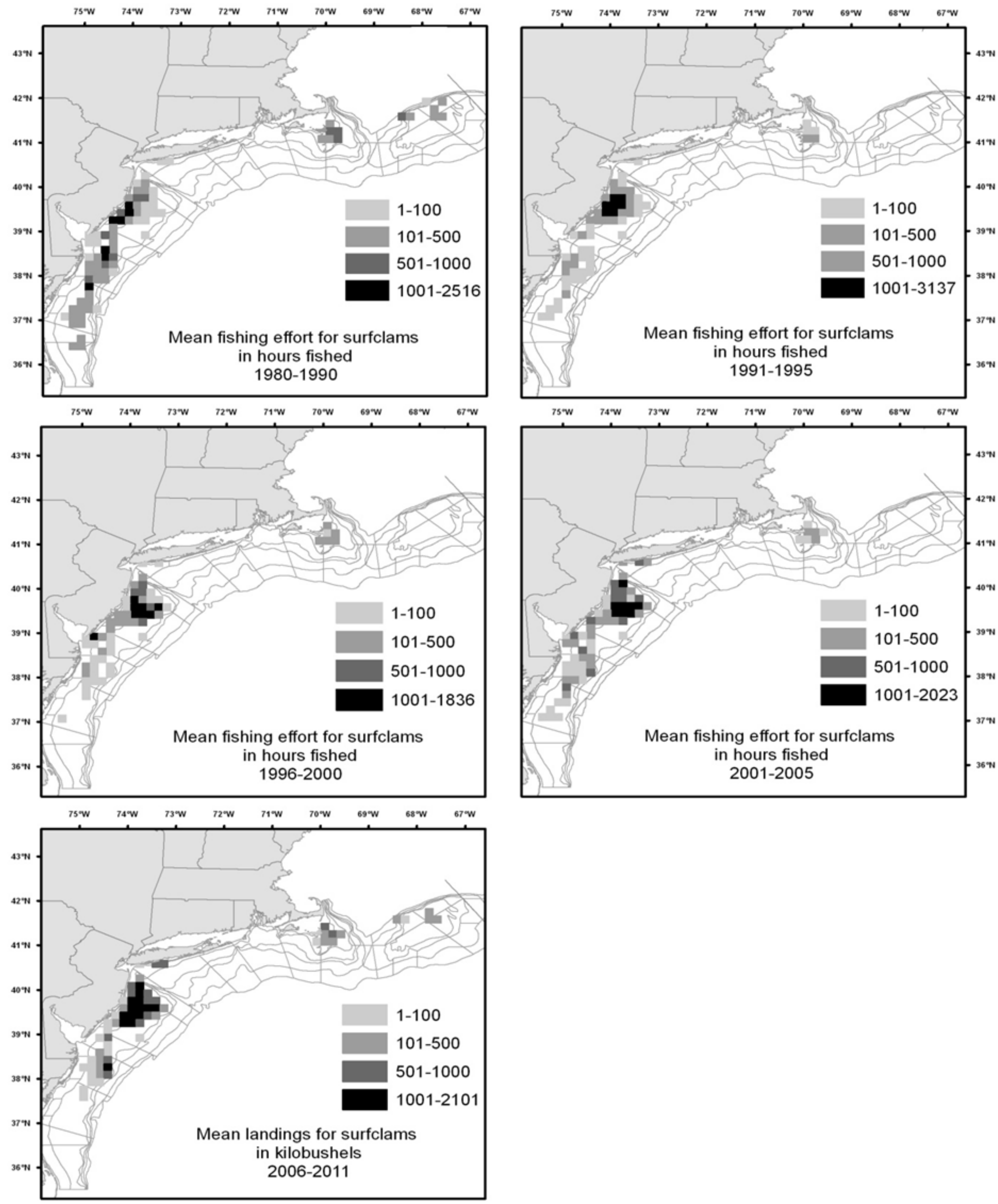


Figure A9. Average surfclam effort by ten-minute squares

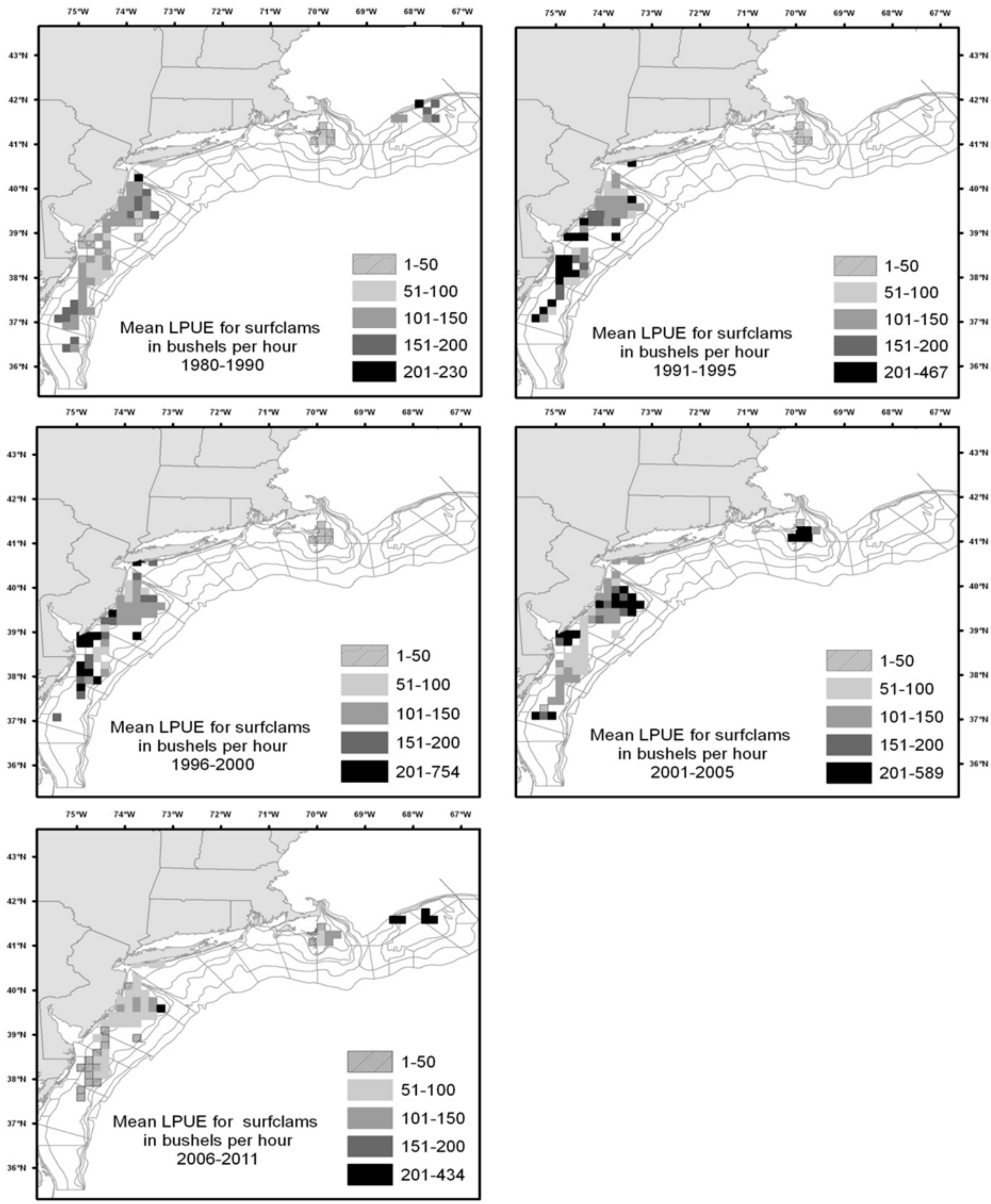


Figure A10. Average surfclam LPUE (bu. h^{-1}) by ten-minute squares over time.

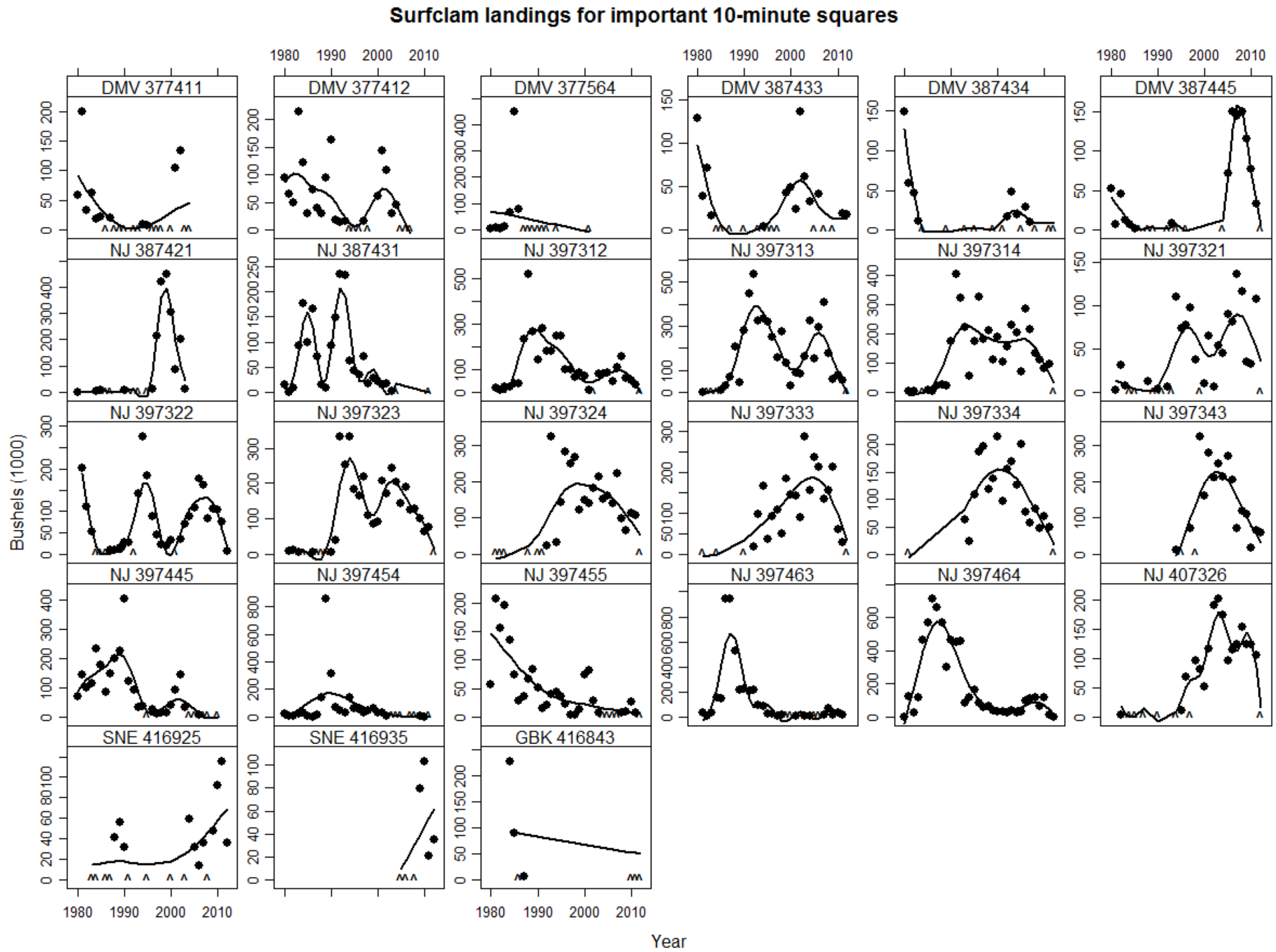


Figure A11. Annual surfclam landings in “important” ten minute squares (TNMS) during 1980-2012 based on logbook data. Important means that a square ranked in the top 10 TNMS for total landings during any five-year period (1980-1984, 1985-1989, …, 2000-2004, 2005-2009, 2010-2012). Data for 2012 are incomplete and preliminary. To protect the privacy of individual firms, data are not plotted if the number of vessels is less than 2. Instead, a “^” is shown on the x-axis to indicate where data are missing. The solid dark line is a spline intended to show trends. The spline was fit too all available data, including data not plotted.

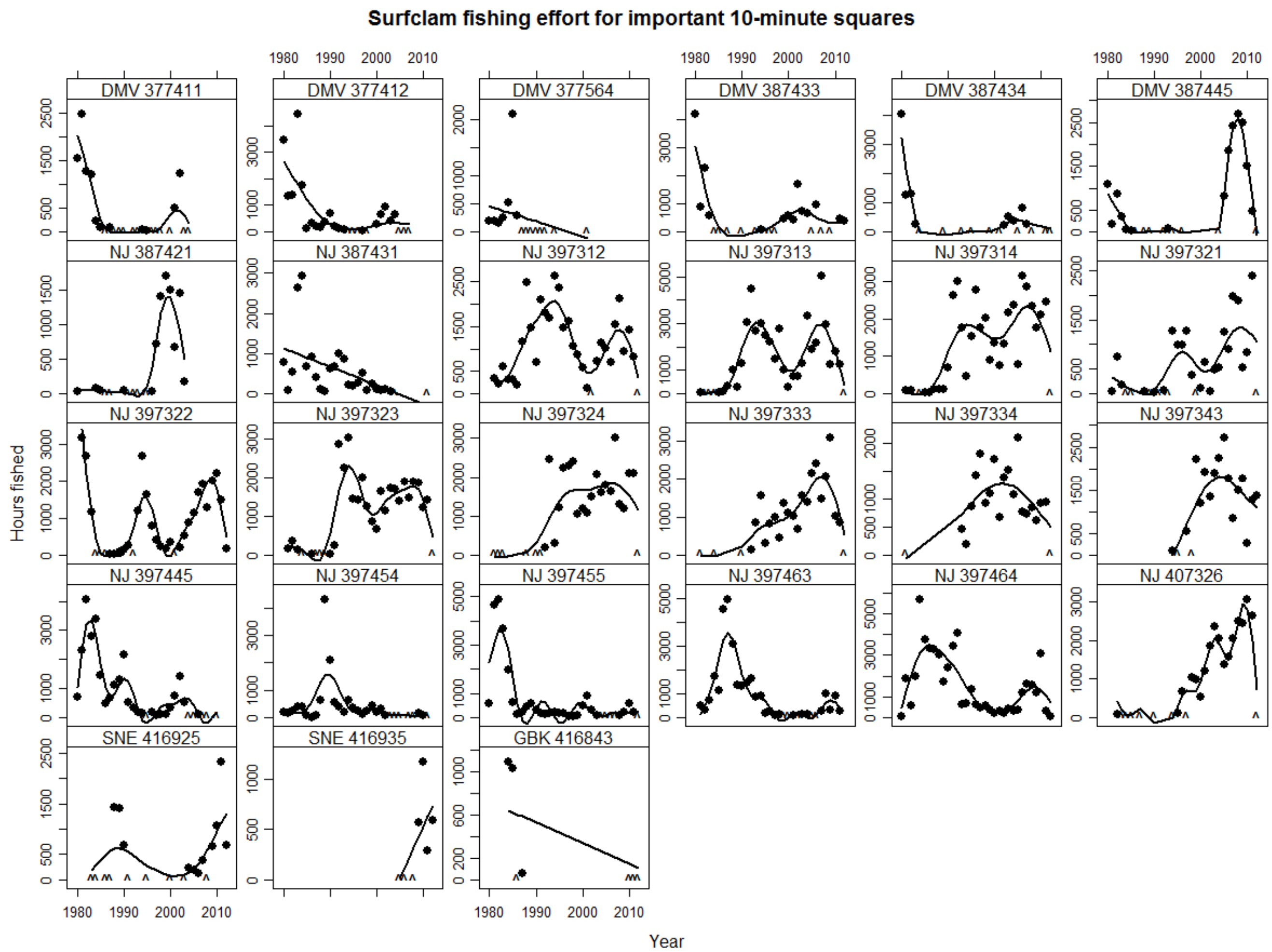


Figure A12. Annual surfclam effort (hours y^{-1}) in “important” ten minute squares (TNMS) during 1980-2012 based on logbook data. Important means that a square ranked in the top 10 TNMS for effort during any five-year period (1980-1984, 1985-1989, …, 2000-2004, 2005-2009, 2010-2012). Data for 2012 are incomplete and preliminary. To protect the privacy of individual firms, data are not plotted if the number of vessels is less than 2. Instead, a “^” is shown on the x-axis to indicate where data are missing. The solid dark line is a spline intended to show trends. The spline was fit too all available data, including data not plotted.

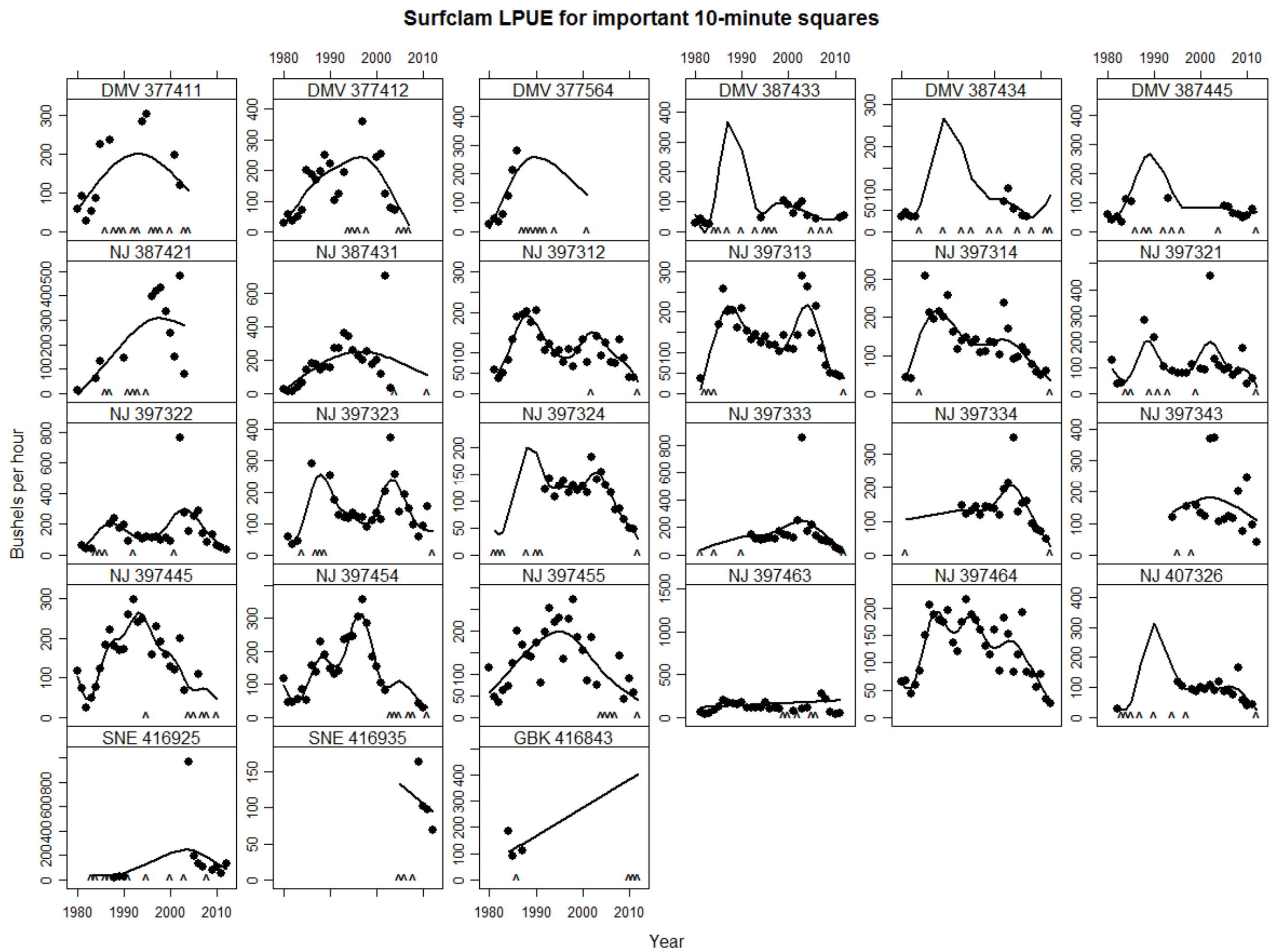


Figure A13. Annual surfclam LPUE (bu h^{-1}) in "important" ten minute squares (TNMS) during 1980-2012 based on logbook data. Important means that a square ranked in the top 10 TNMS for total LPUE during any five-year period (1980-1984, 1985-1989, …, 2000-2004, 2005-2009, 2010-2012). Data for 2012 are incomplete and preliminary. To protect the privacy of individual firms, data are not plotted if the number of vessels is less than 2. Instead, a "^" is shown on the x-axis to indicate where data are missing. The solid dark line is a spline intended to show trends. The spline was fit too all available data, including data not plotted.

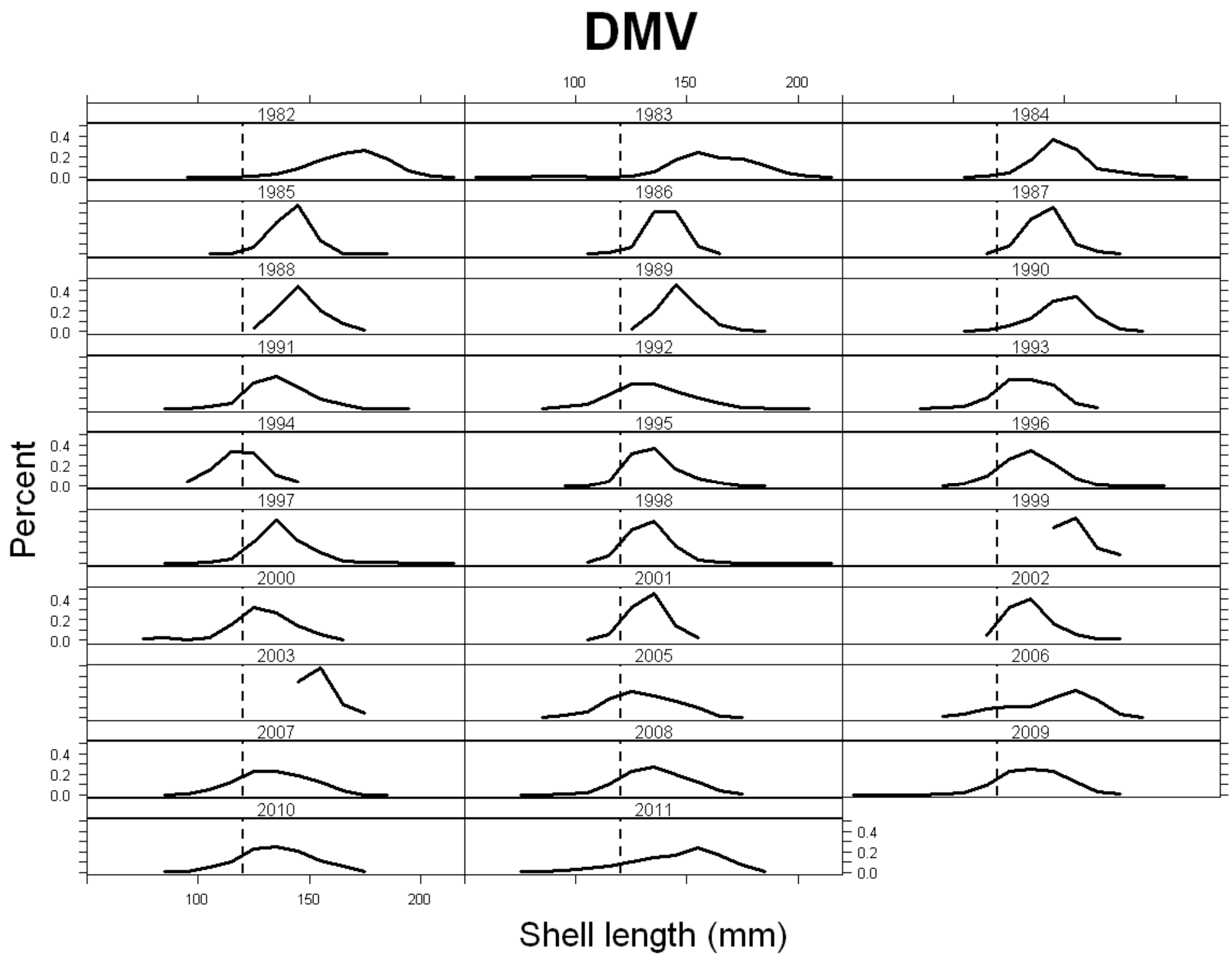


Figure A14. Length compositions of port-sampled landed surfclams from the DMV region.

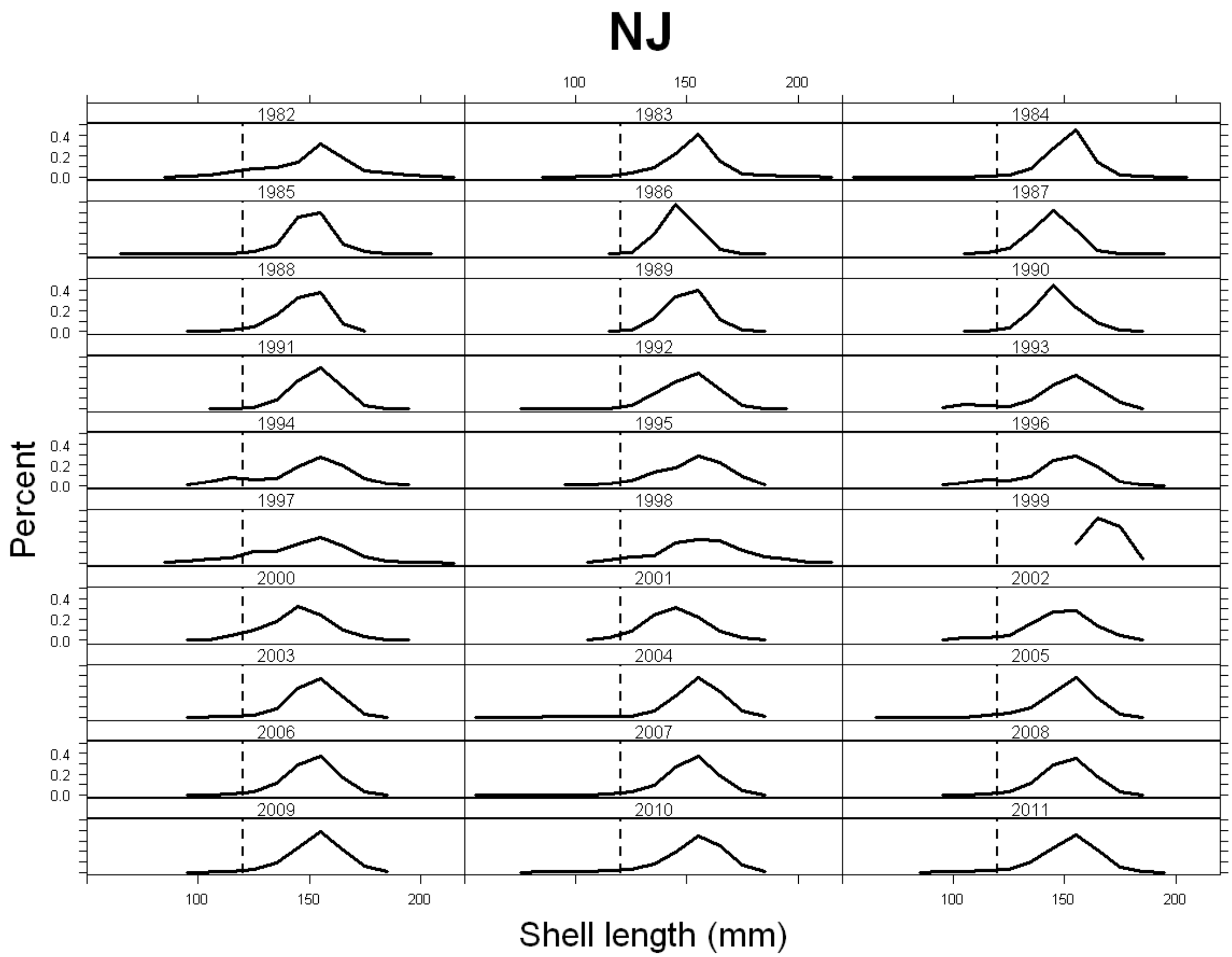


Figure A15. Length compositions of port-sampled landed surfclams from the NJ region.

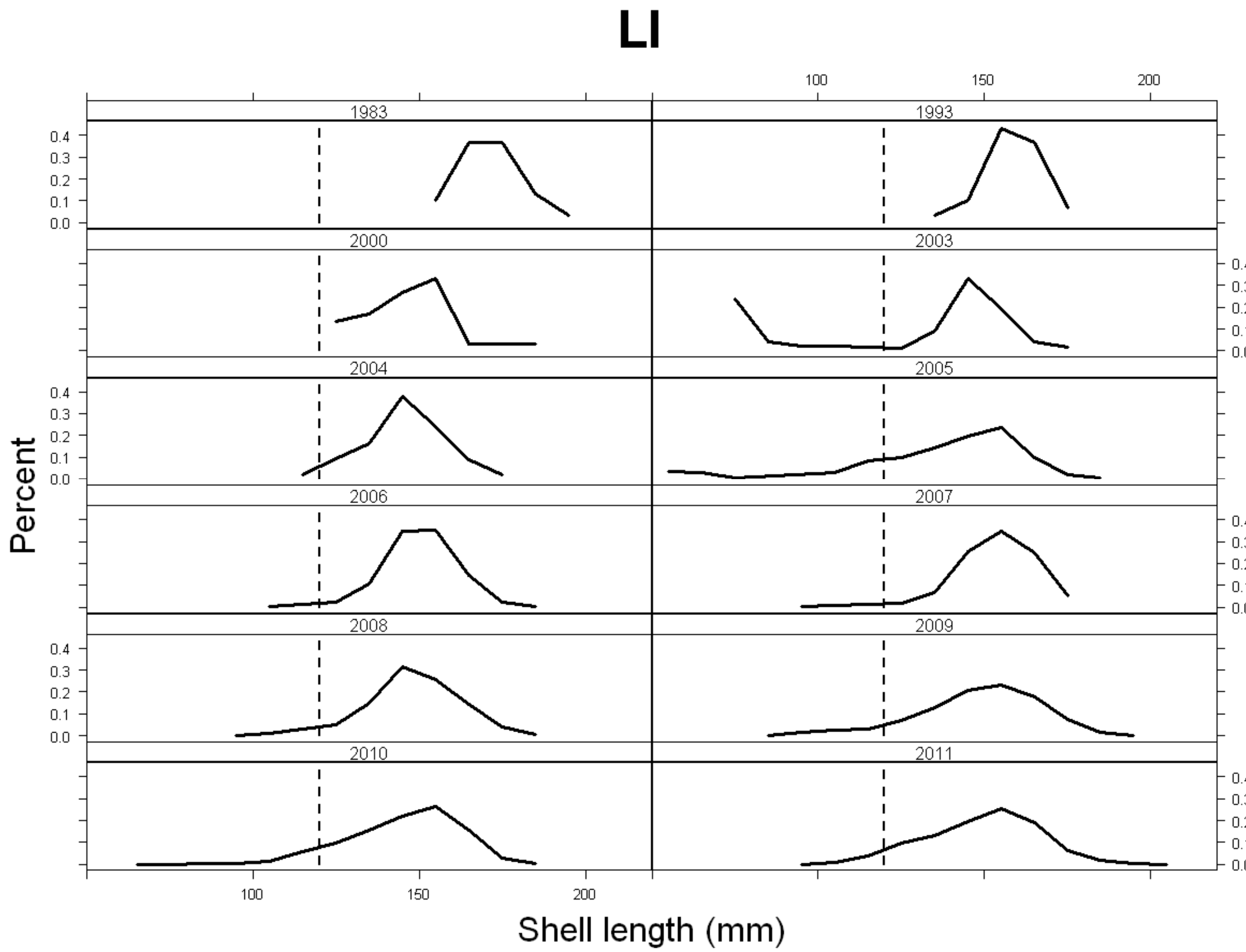


Figure A16. Length compositions of port-sampled landed surfclams from the LI region.

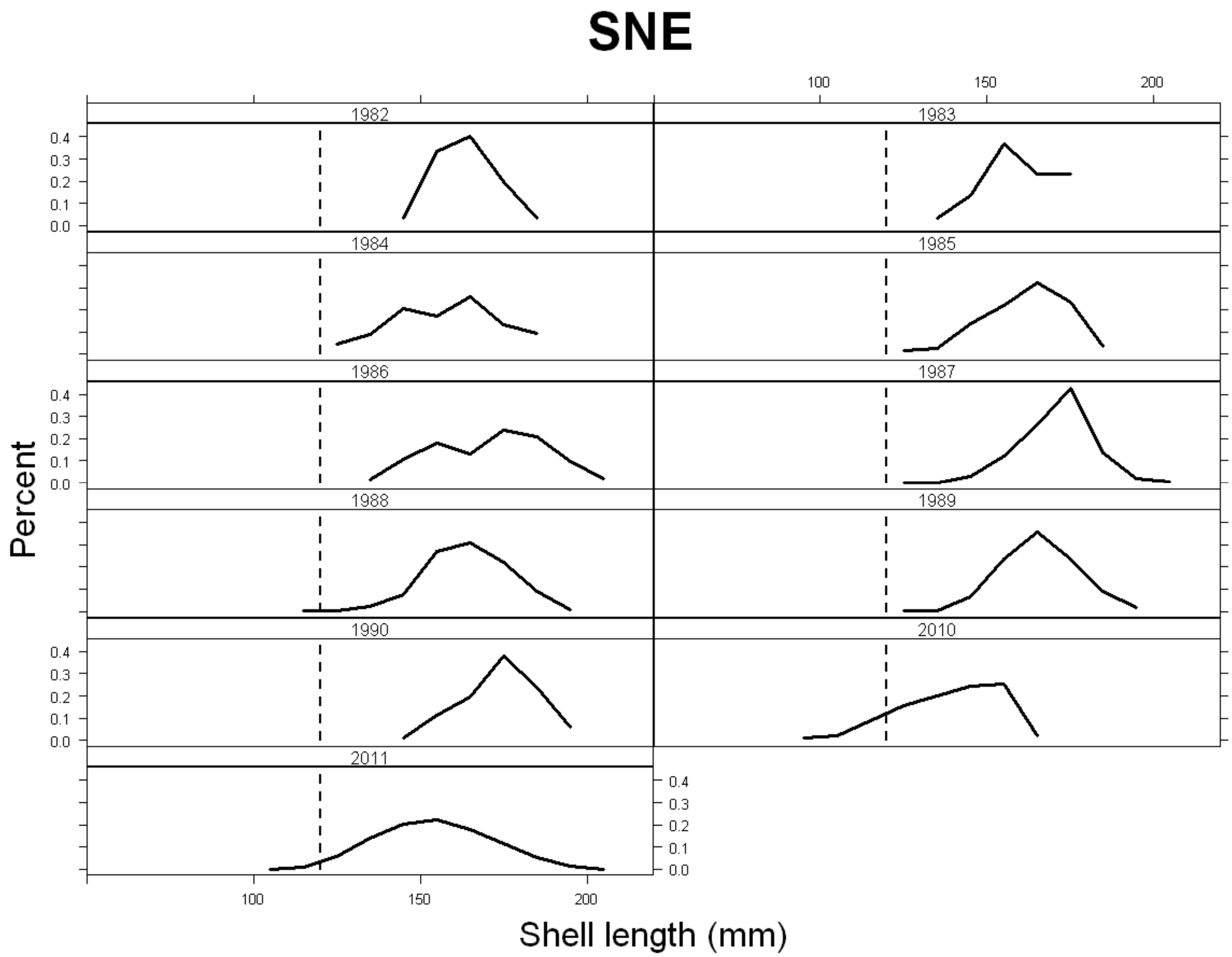


Figure A17. Length compositions of port-sampled landed surfclams from the SNE region.

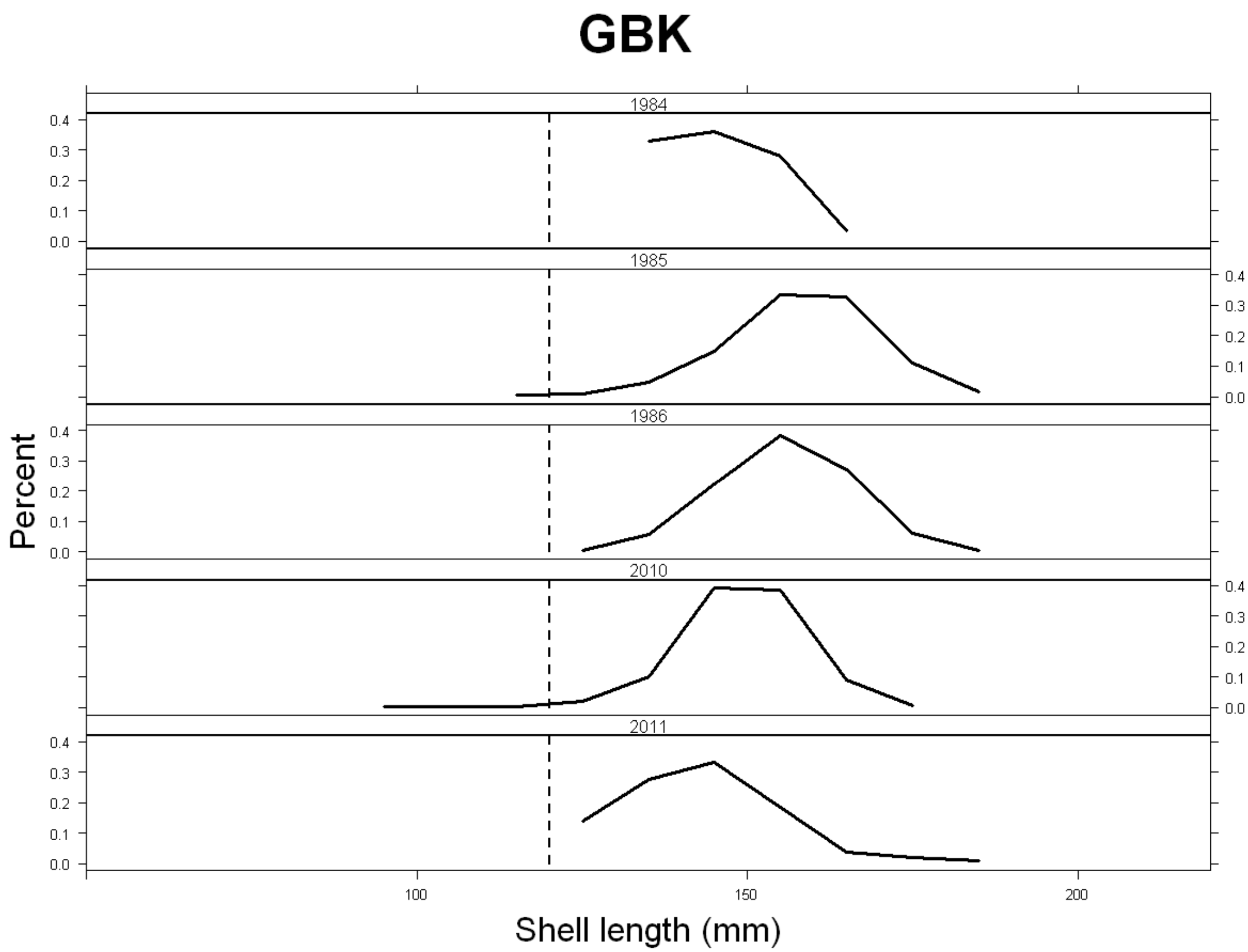


Figure A18. Length compositions of port-sampled landed surfclams from the GBK region.

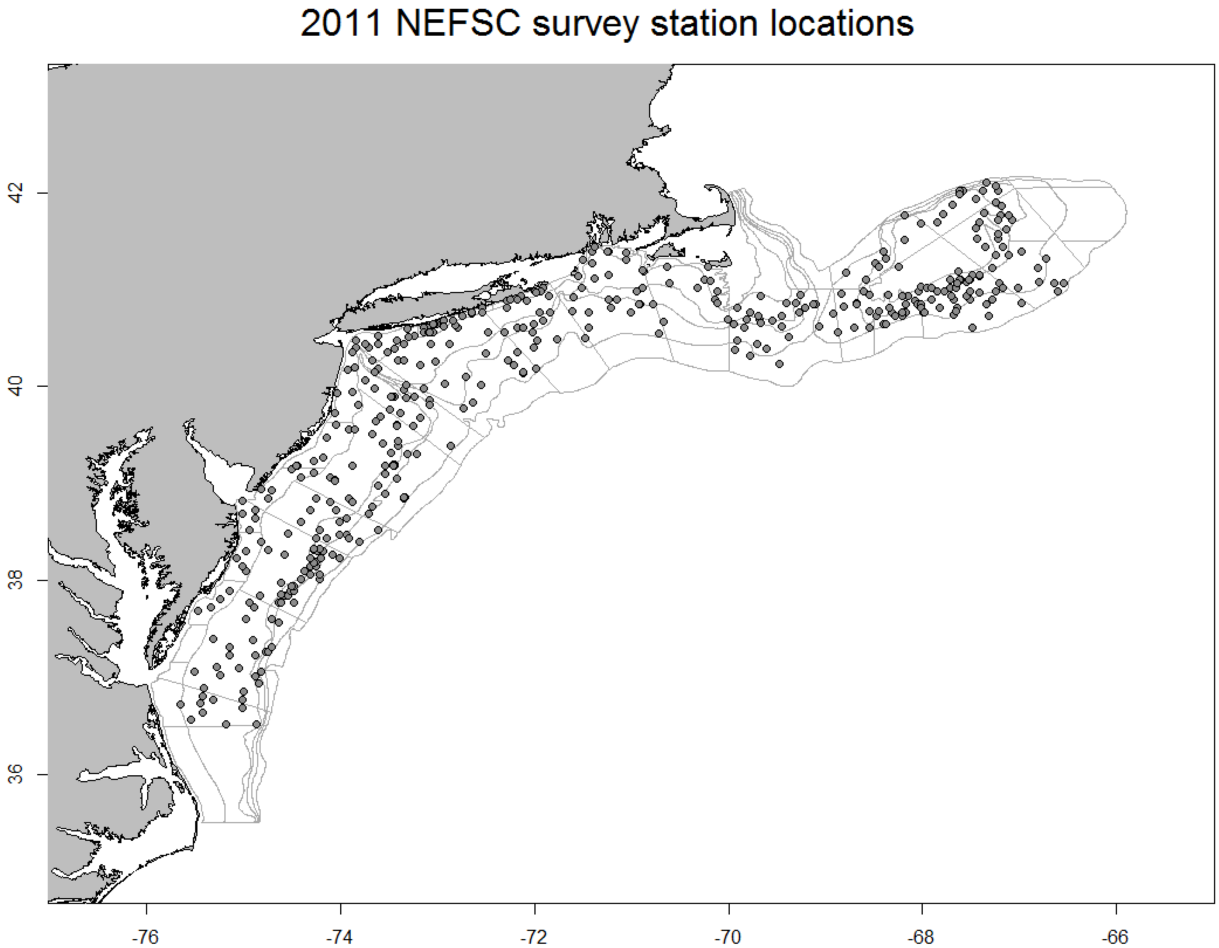


Figure A19. Station locations from the 2011 NEFSC survey

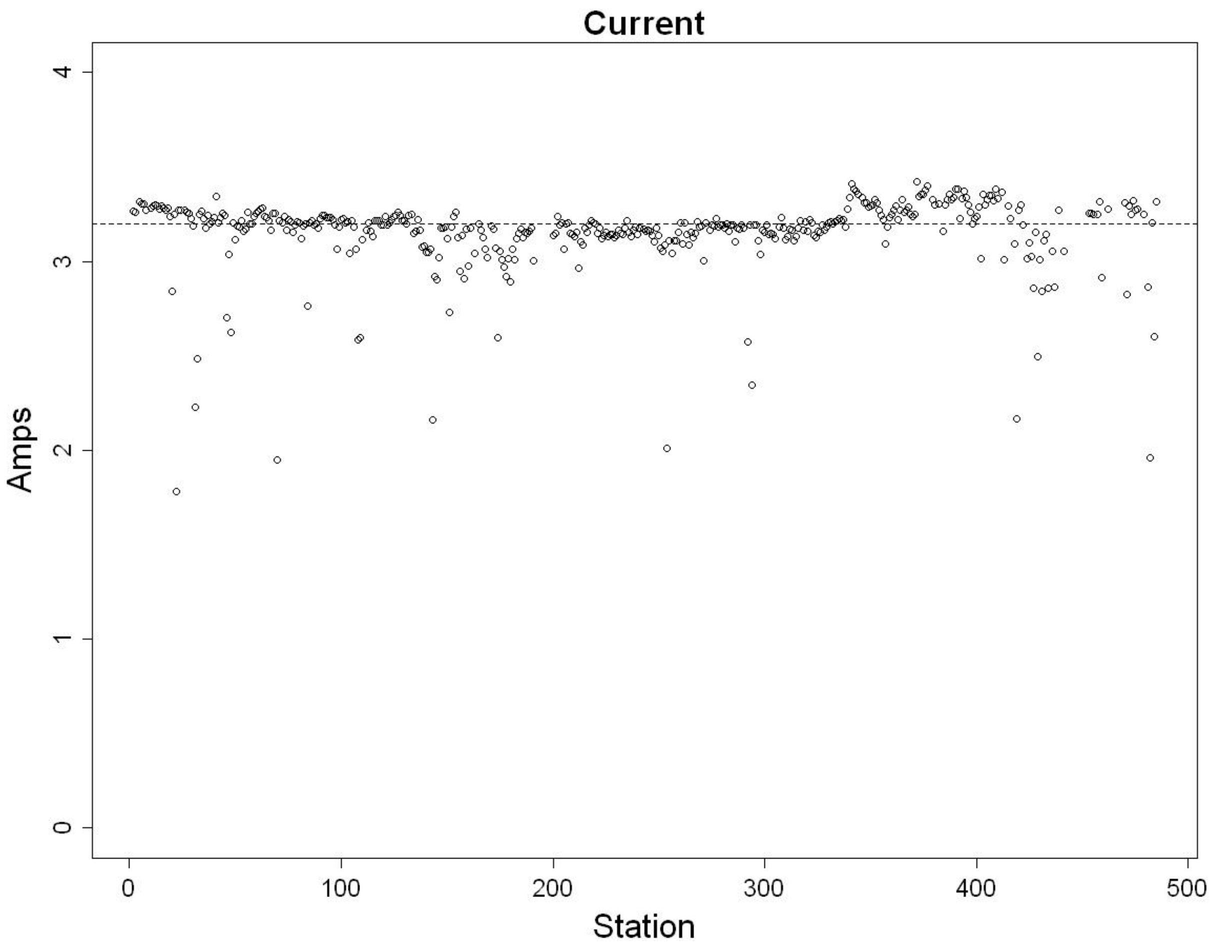


Figure A20. Amperage by tow for the 2011 NEFSC clam survey. The dashed line is for reference only.

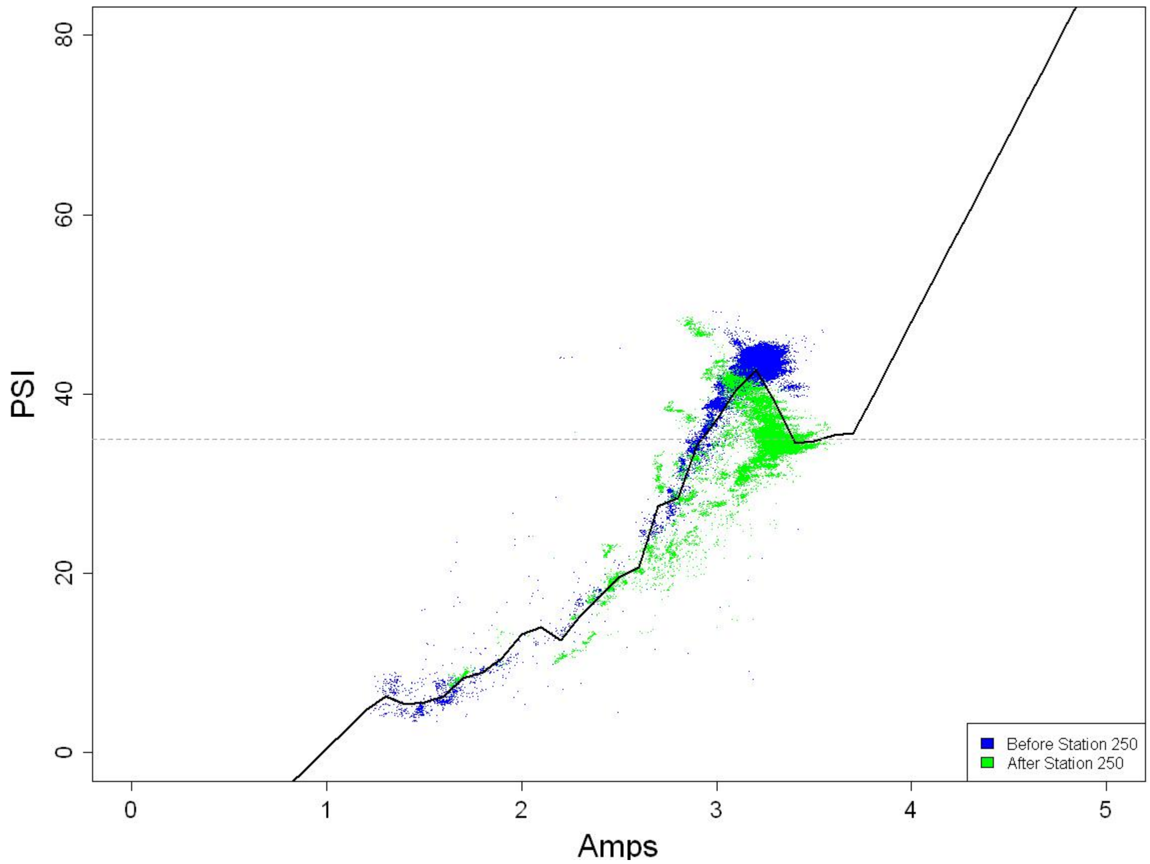


Figure A21. The relationship between amperage and differential pressure over all fishing seconds while the SSP was operational. The blue dots are observations recorded before the SSP failed at station 161 and the green dots are observations after the SSP began working again at station 371. The line plotted is the cubic spline fit to the data.

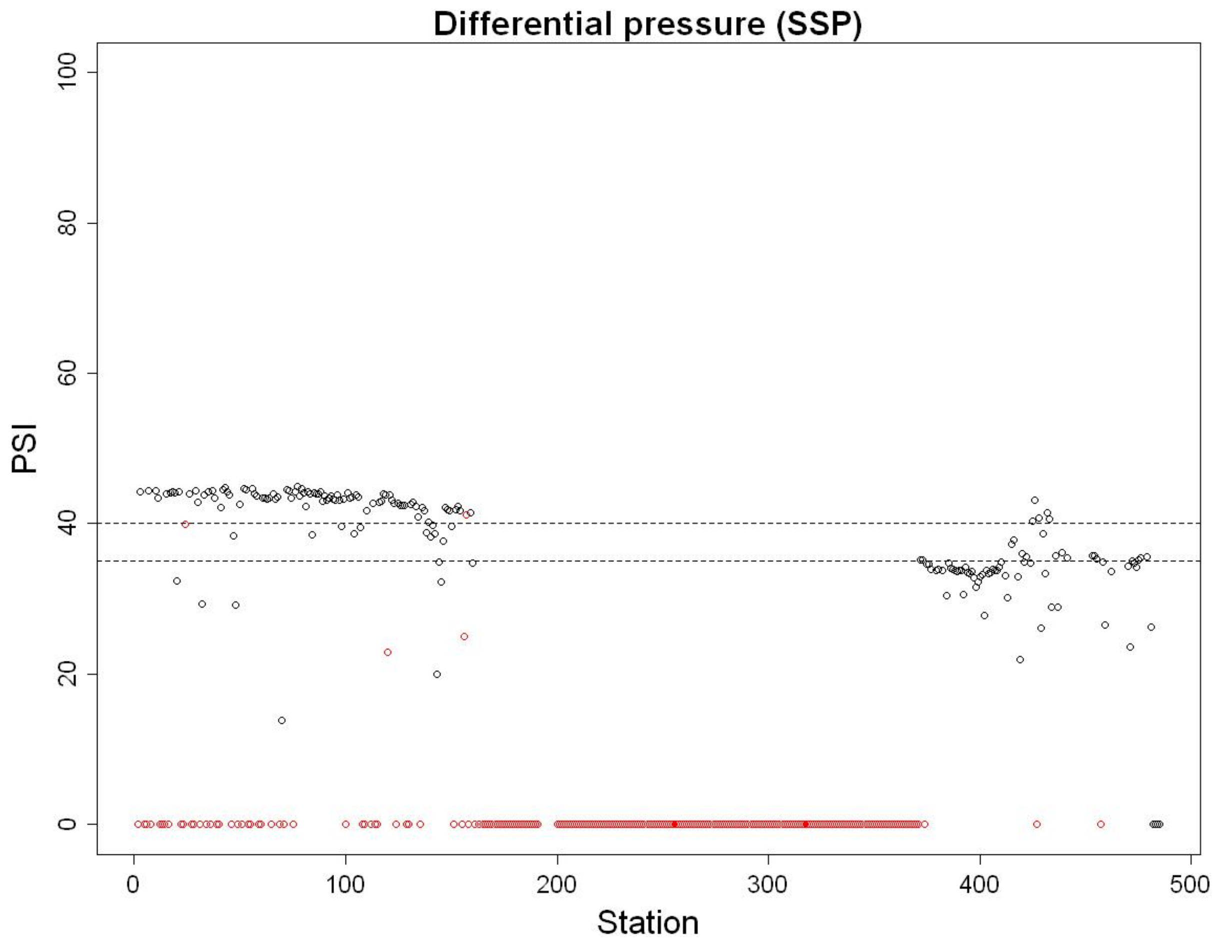


Figure A22. Differential pressure by tow during the 2011 NEFSC survey. The black circles are tows for which differential pressure was recorded by the SSP and the red circles are tows for which there is no SSP data. The dashed lines represent the upper and lower bounds for differential pressure tolerance found for the 2009 survey.

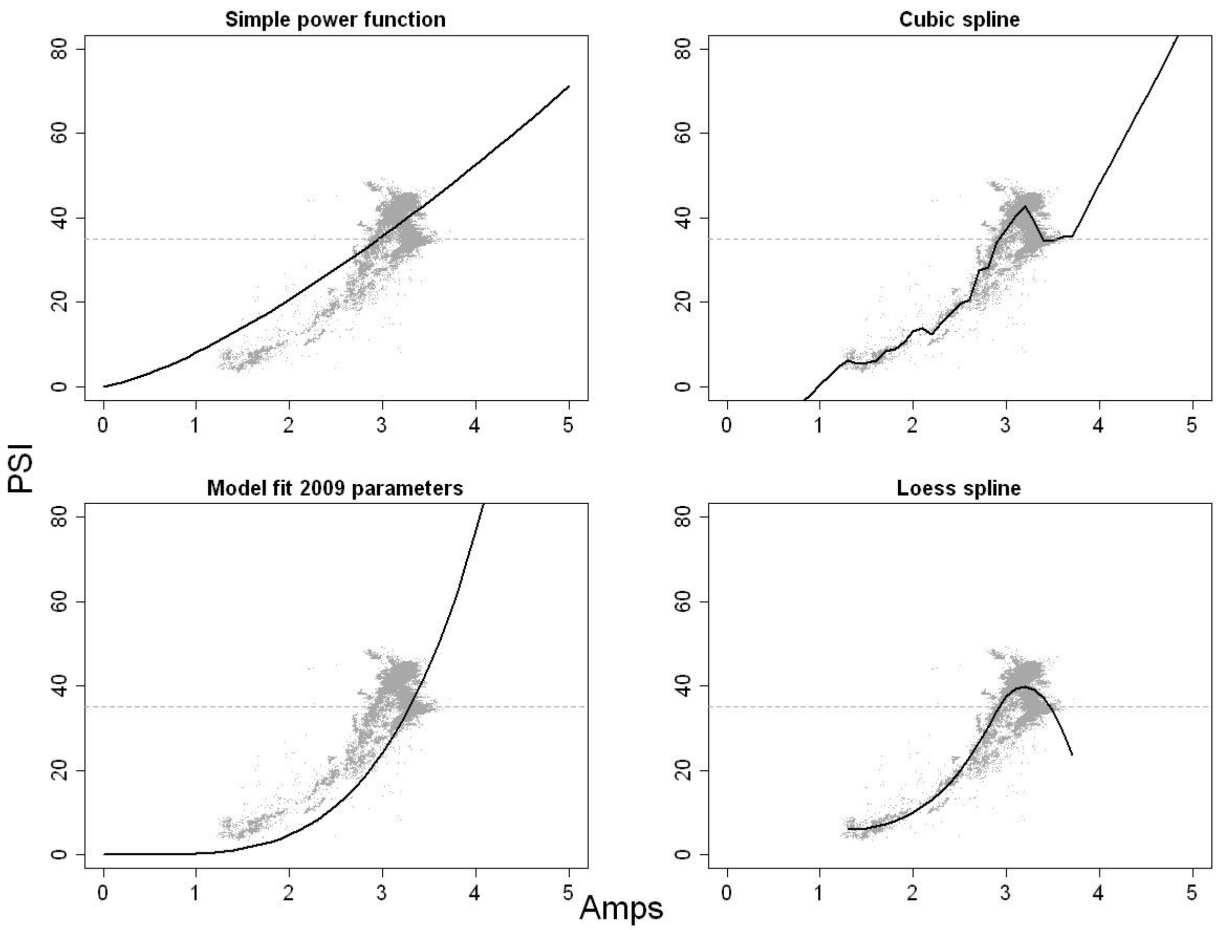


Figure A23. Model fits from four competing models to predict differential pressure from current supplied to the dredge pump on the 2011 NEFSC survey. The tolerance for adequate pump pressure (35 PSI) is shown with the dashed gray line.

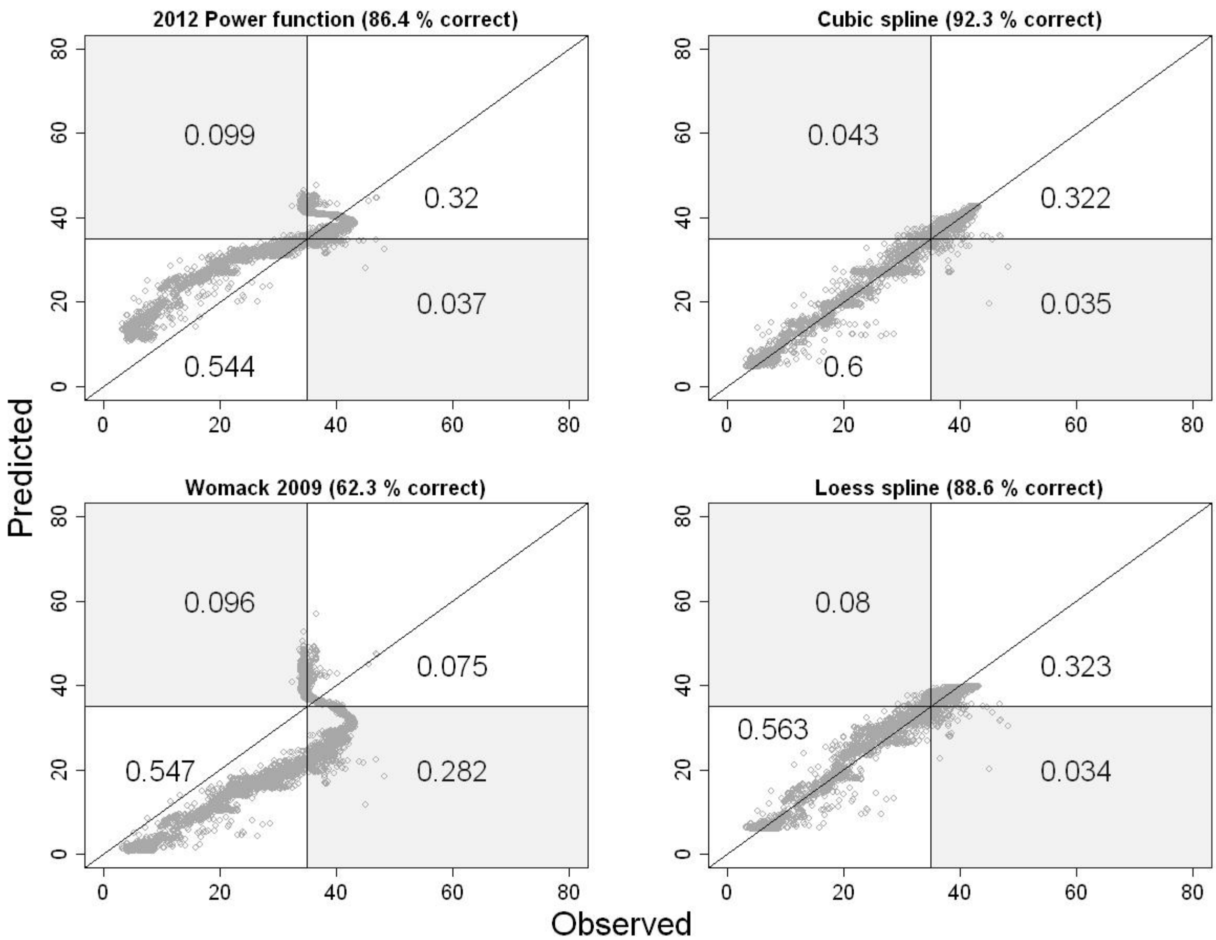


Figure A24. A comparison of four different models used to predict differential pressure from current. The shaded areas represent quadrants where the predicted and observed values disagree regarding the acceptability of a differential pressure measurement. The unshaded quadrants are areas where the predicted and observed values are in agreement. The numbers inside the plot area represent the fraction of points that fall within quadrant. Differential pressures less than 35 PSI are below tolerance for a successful fishing second. The predicted = observed line is also shown for reference.

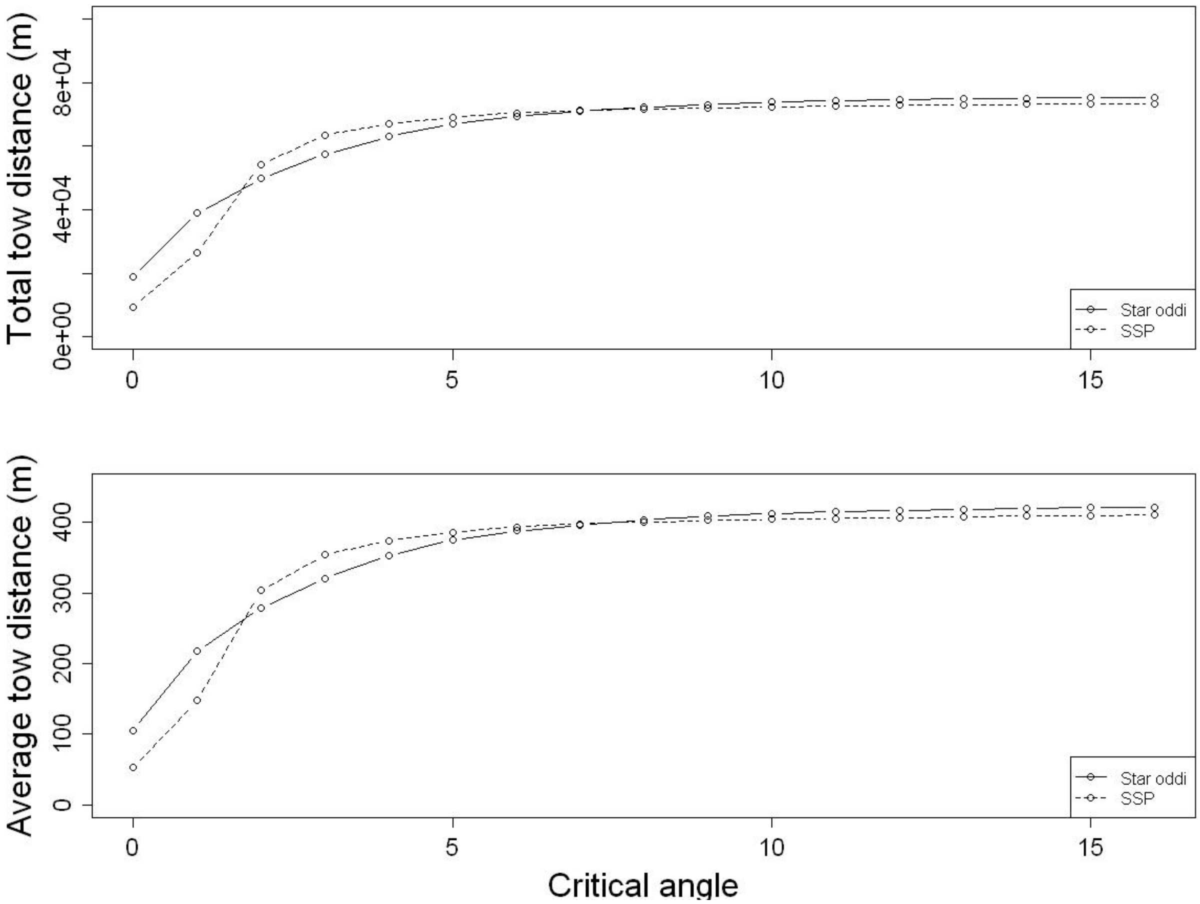


Figure A25. Average and total tow distance over all stations by critical dredge angle

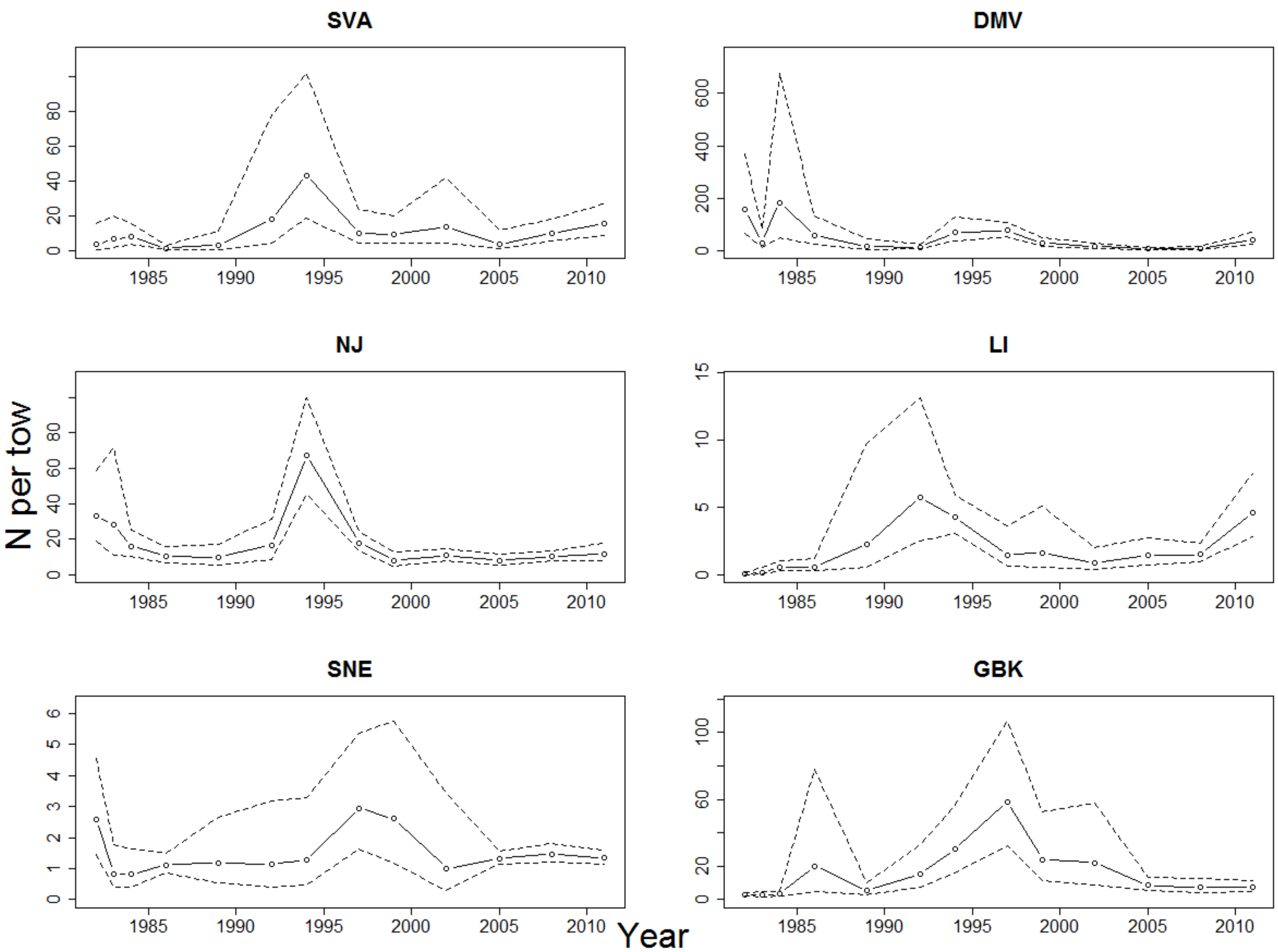


Figure A26. Surfclam 50 – 119 mm SL from NEFSC surveys adjusted for selectivity, with approximate 95% asymmetric confidence intervals, by region.

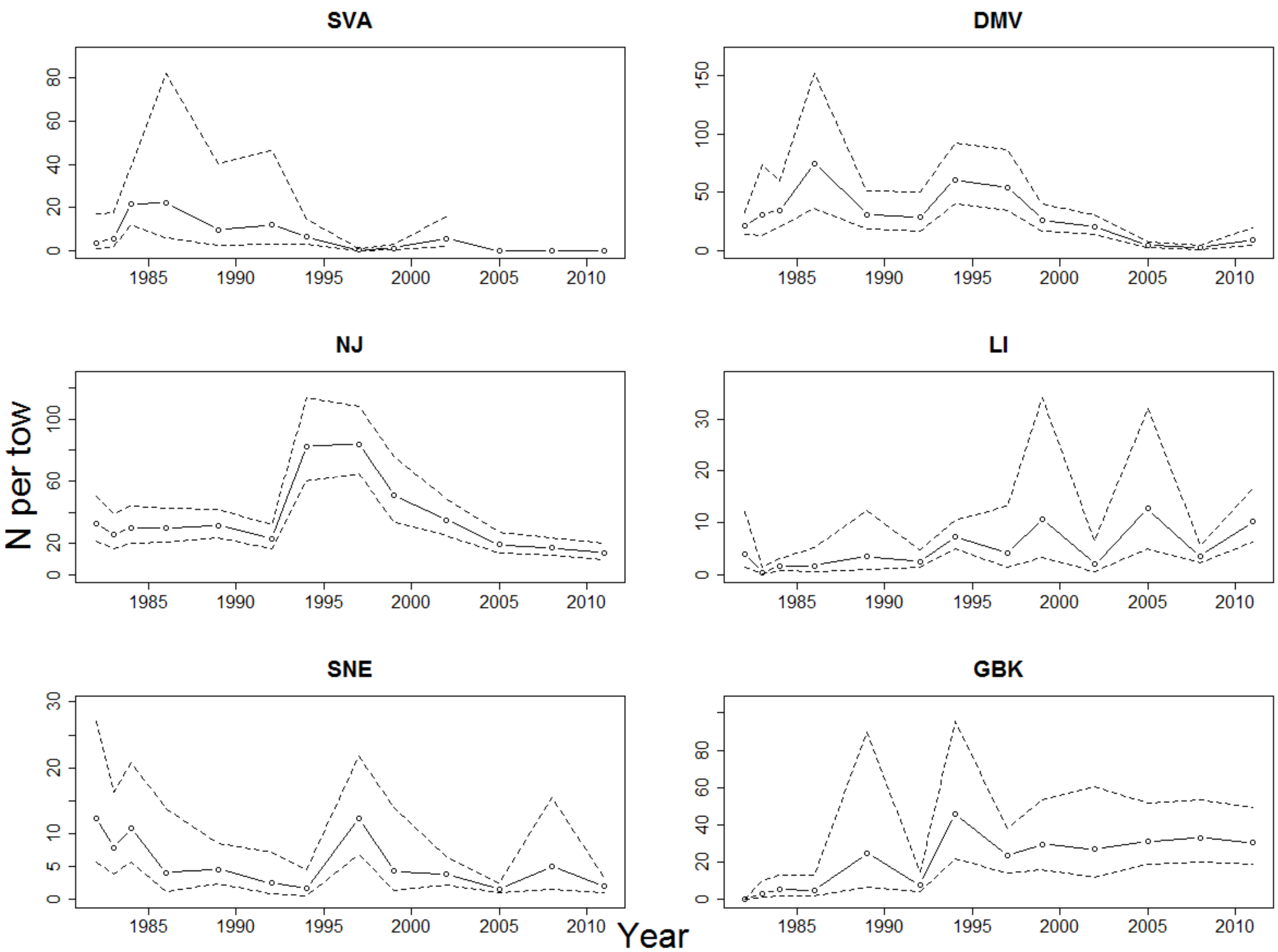


Figure A27. Surfclam larger than 120 mm SL from NEFSC surveys adjusted for selectivity, with approximate 95% asymmetric confidence intervals, by region.

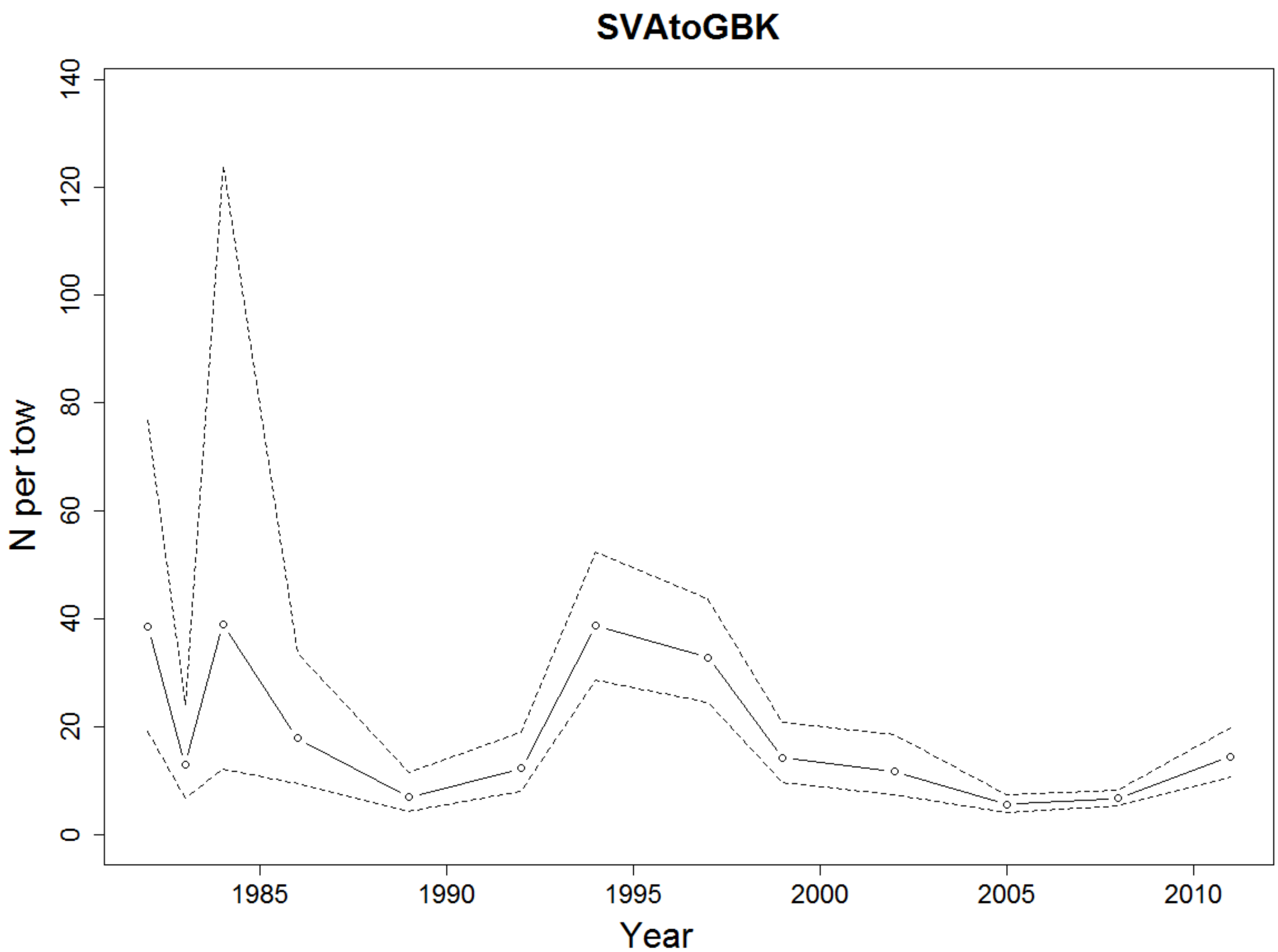


Figure A28. Surfclam 50 – 119 mm SL from NEFSC surveys adjusted for selectivity, with approximate 95% asymmetric confidence intervals for the whole stock.

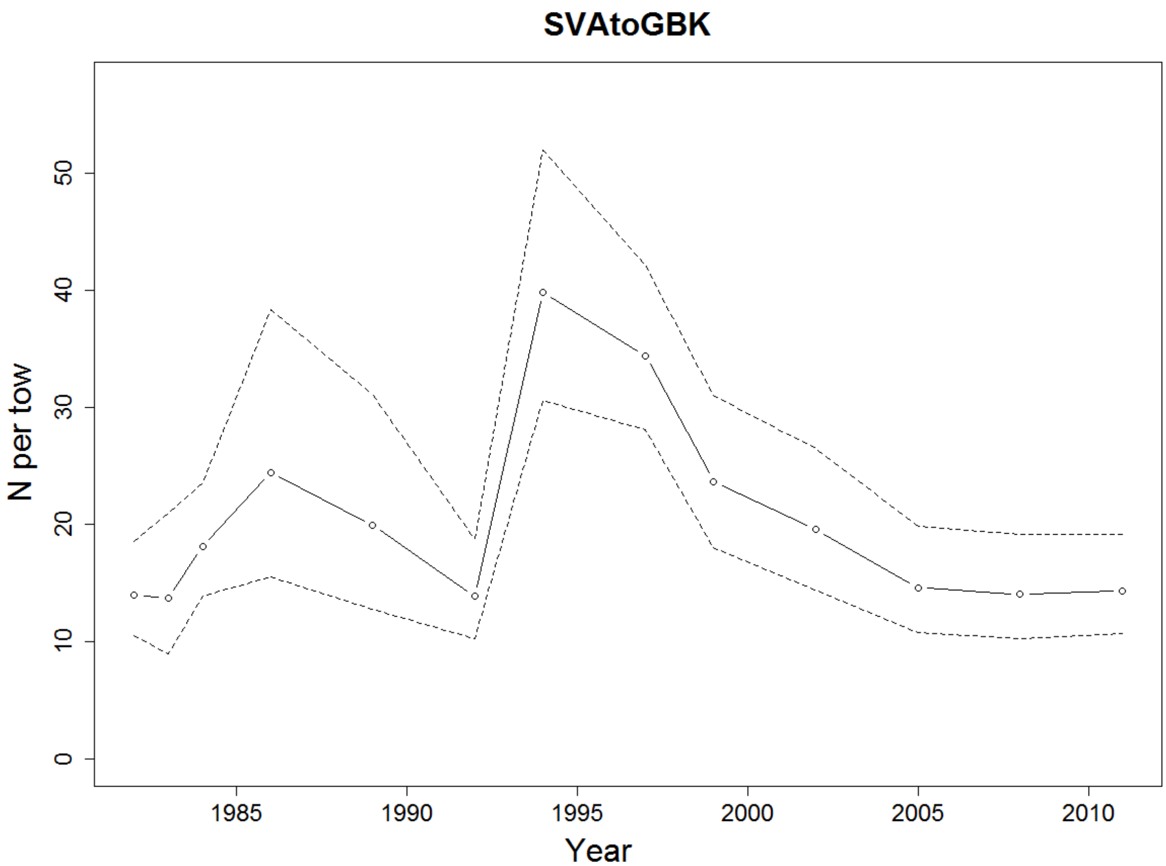
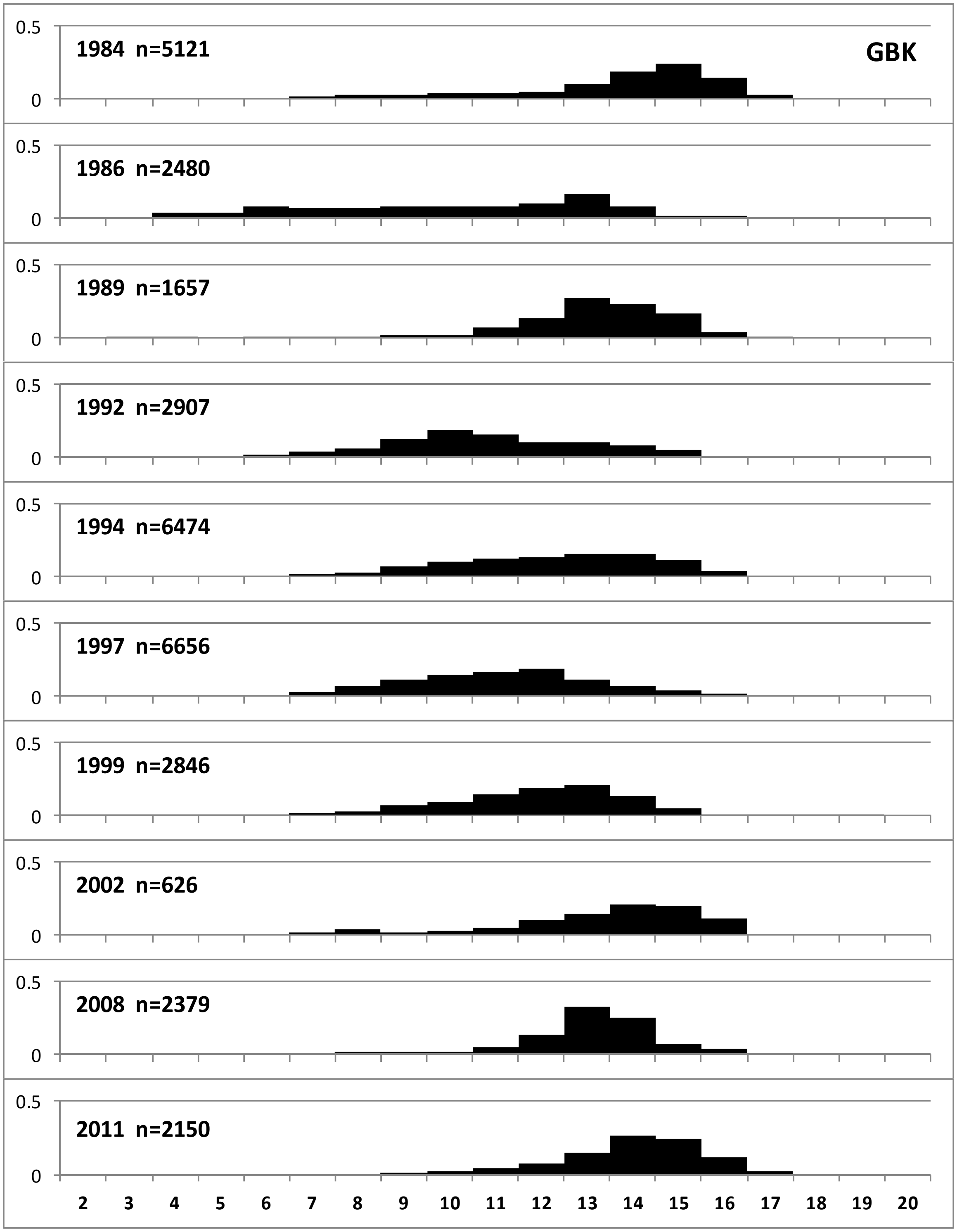
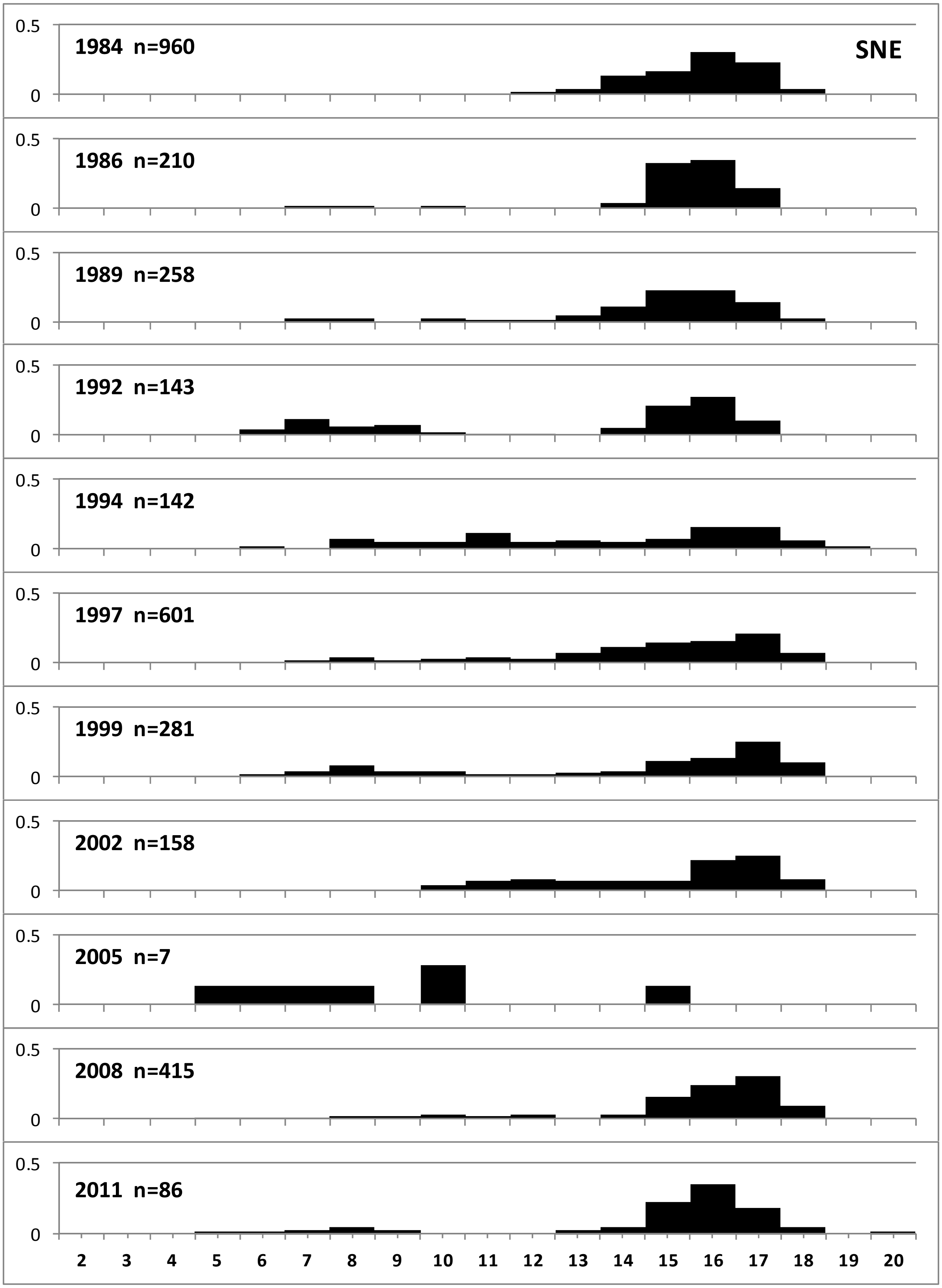
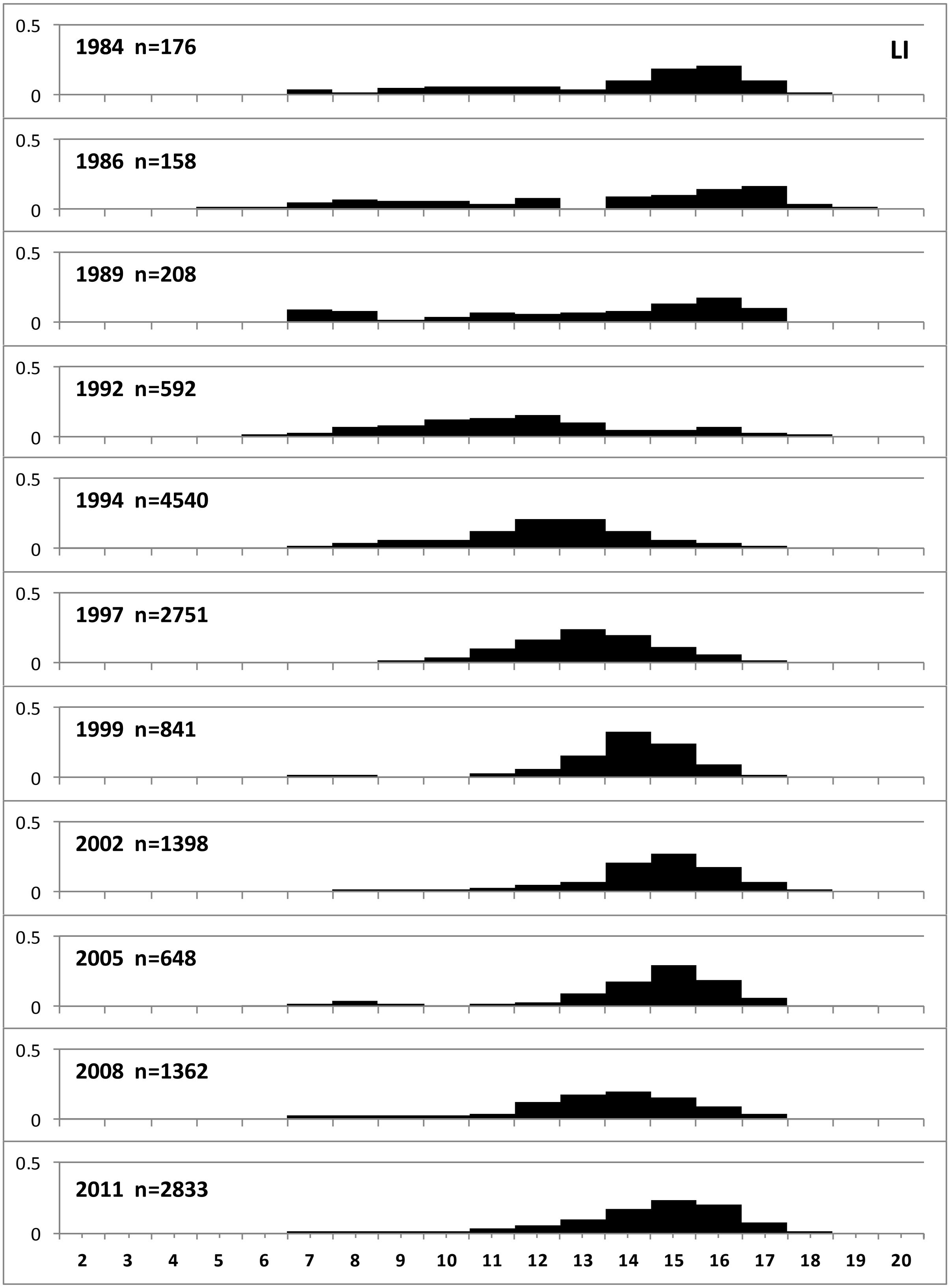


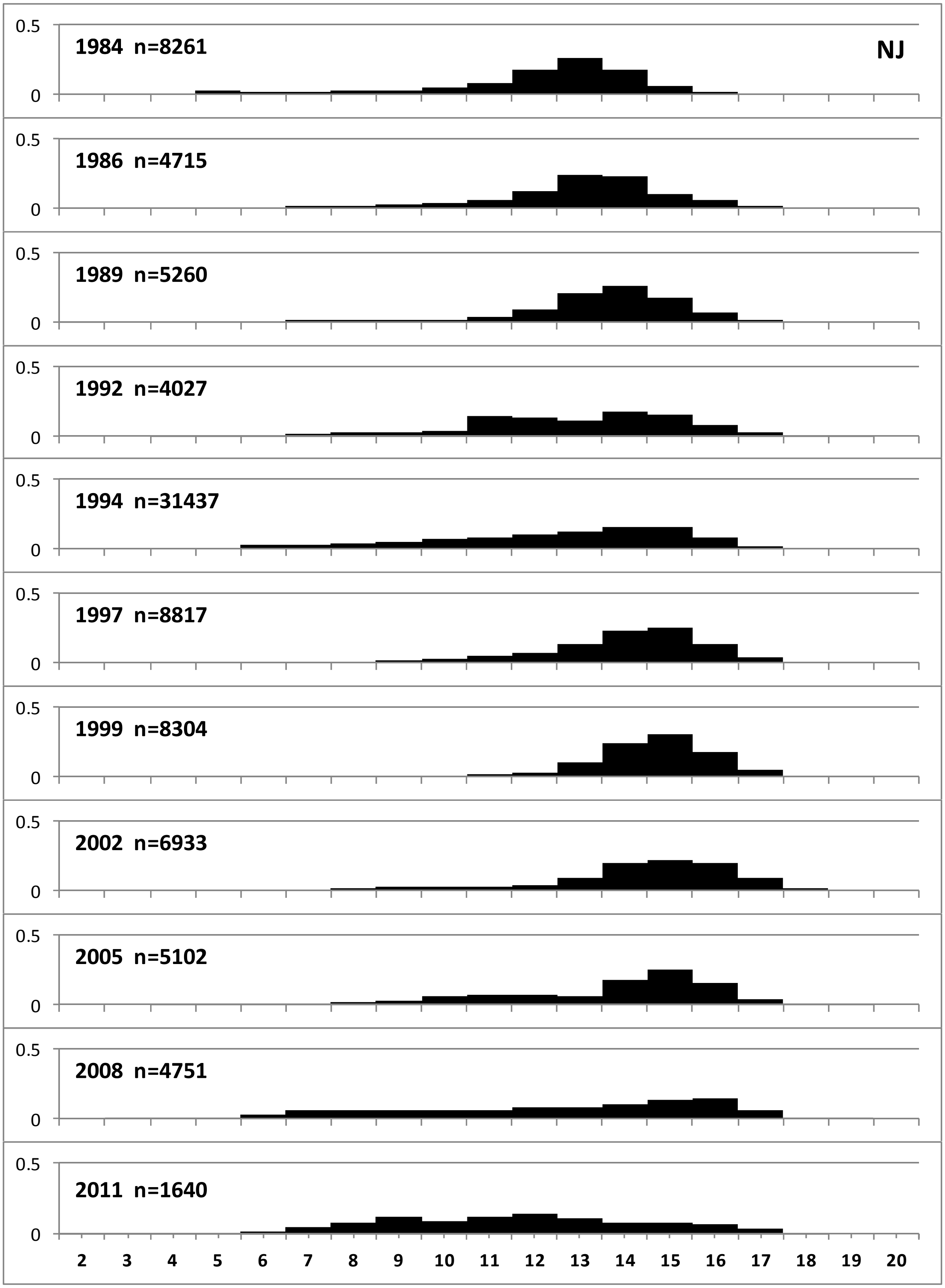
Figure A29. Surfclam larger than 120 mm SL from NEFSC surveys adjusted for selectivity, with approximate 95% asymmetric confidence intervals, for the whole stock.

Figure A30. (Following pages) Survey length composition by region.

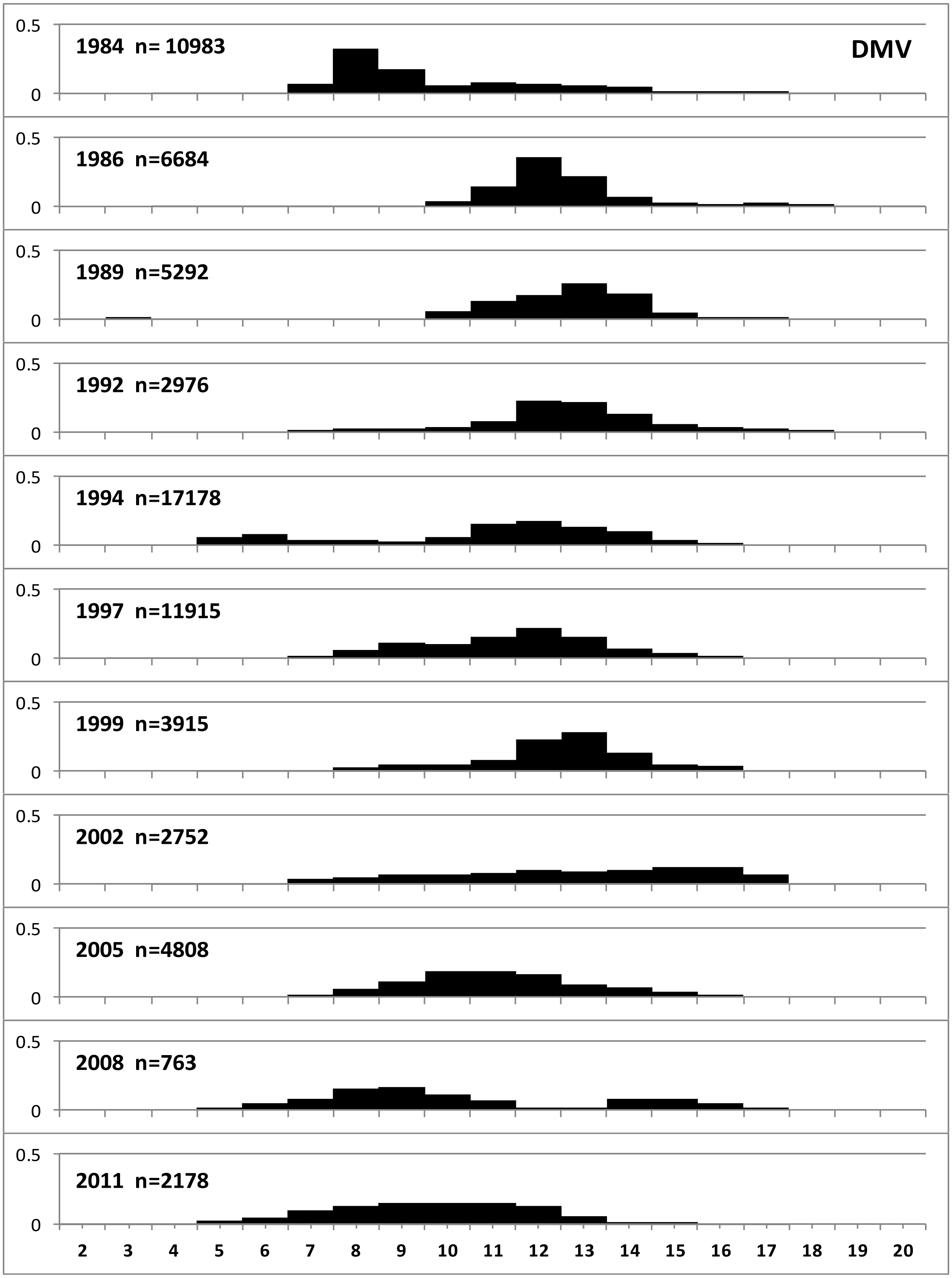

GBK
1984 n=5121
1986 n=2480
1989 n=1657
1992 n=2907
1994 n=6474
1997 n=6656
1999 n=2846
2002 n=626
2008 n=2379
2011 n=2150
0.5
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

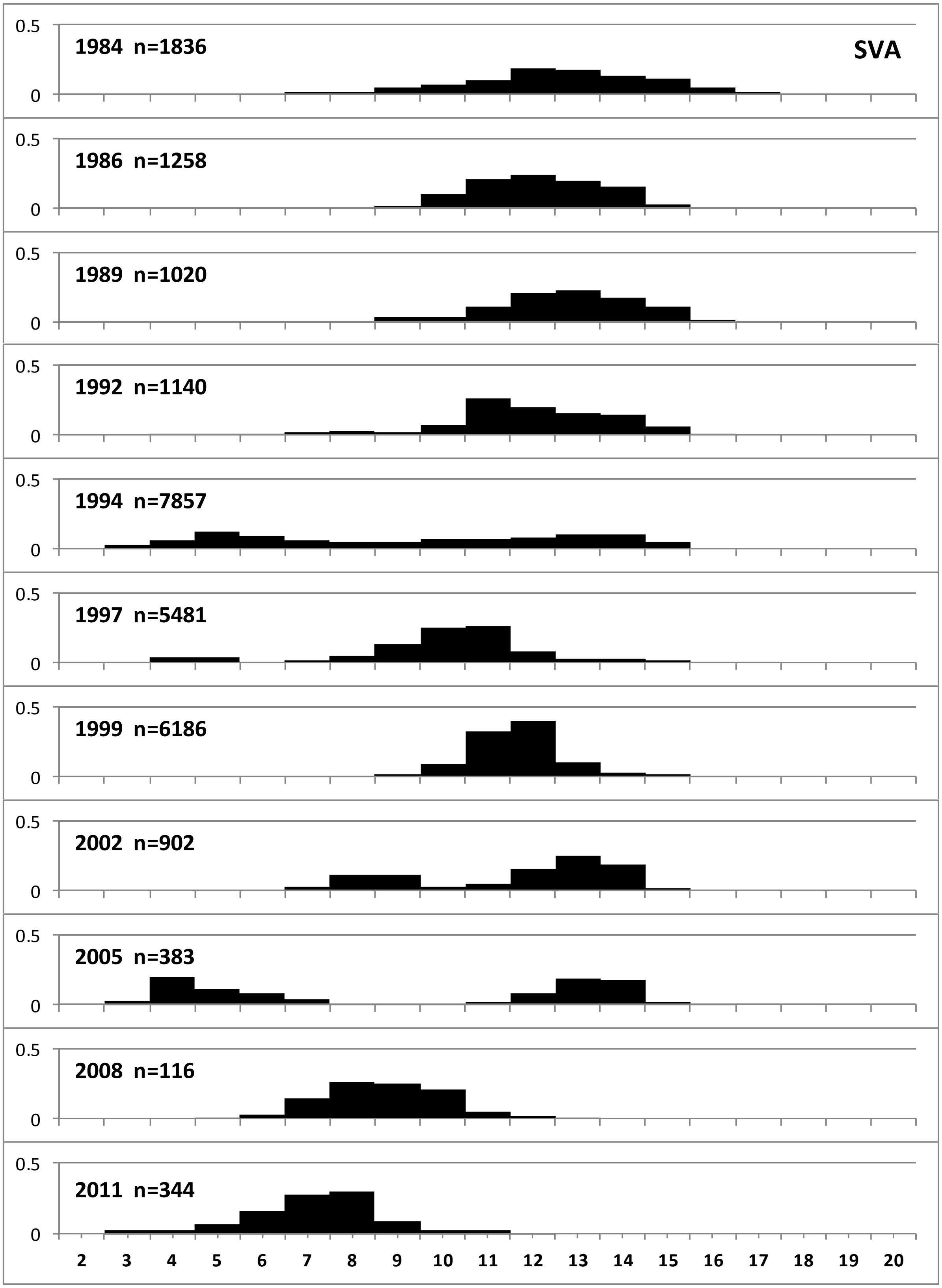

SNE
0.5
0
1984 n=960
1986 n=210
1989 n=258
1992 n=143
1994 n=142
1997 n=601
1999 n=281
2002 n=158
2005 n=7
2008 n=415
2011 n=86
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20


LI
1984 n=176
1986 n=158
1989 n=208
1992 n=592
1994 n=4540
1997 n=2751
1999 n=841
2002 n=1398
2005 n=648
2008 n=1362
2011 n=2833
0.5
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20



0.5
0
1984 n=8261
NJ
1986 n=4715
1989 n=5260
1992 n=4027
1994 n=31437
1997 n=8817
1999 n=8304
2002 n=6933
2005 n=5102
2008 n=4751
2011 n=1640
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20


DMV
1984 n= 10983
1986 n=6684
1989 n=5292
1992 n=2976
1994 n=17178
1997 n=11915
1999 n=3915
2002 n=2752
2005 n=4808
2008 n=763
2011 n=2178
0.5
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20


SVA
1984 n=1836
1986 n=1258
1989 n=1020
1992 n=1140
1994 n=7857
1997 n=5481
1999 n=6186
2002 n=902
2005 n=383
2008 n=116
2011 n=344
0.5
0
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

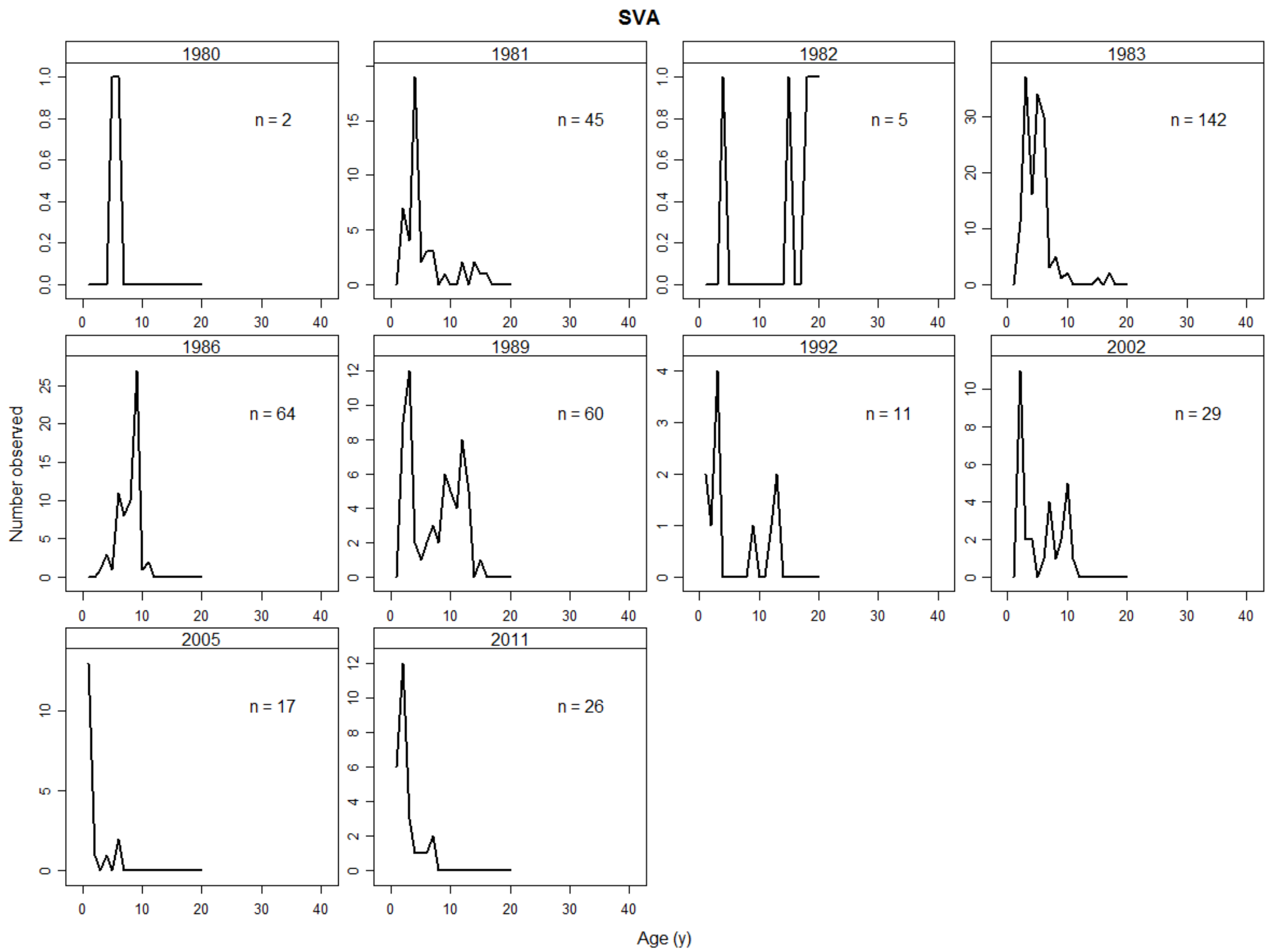


Figure A31. Age composition of NEFSC surveys in SVA

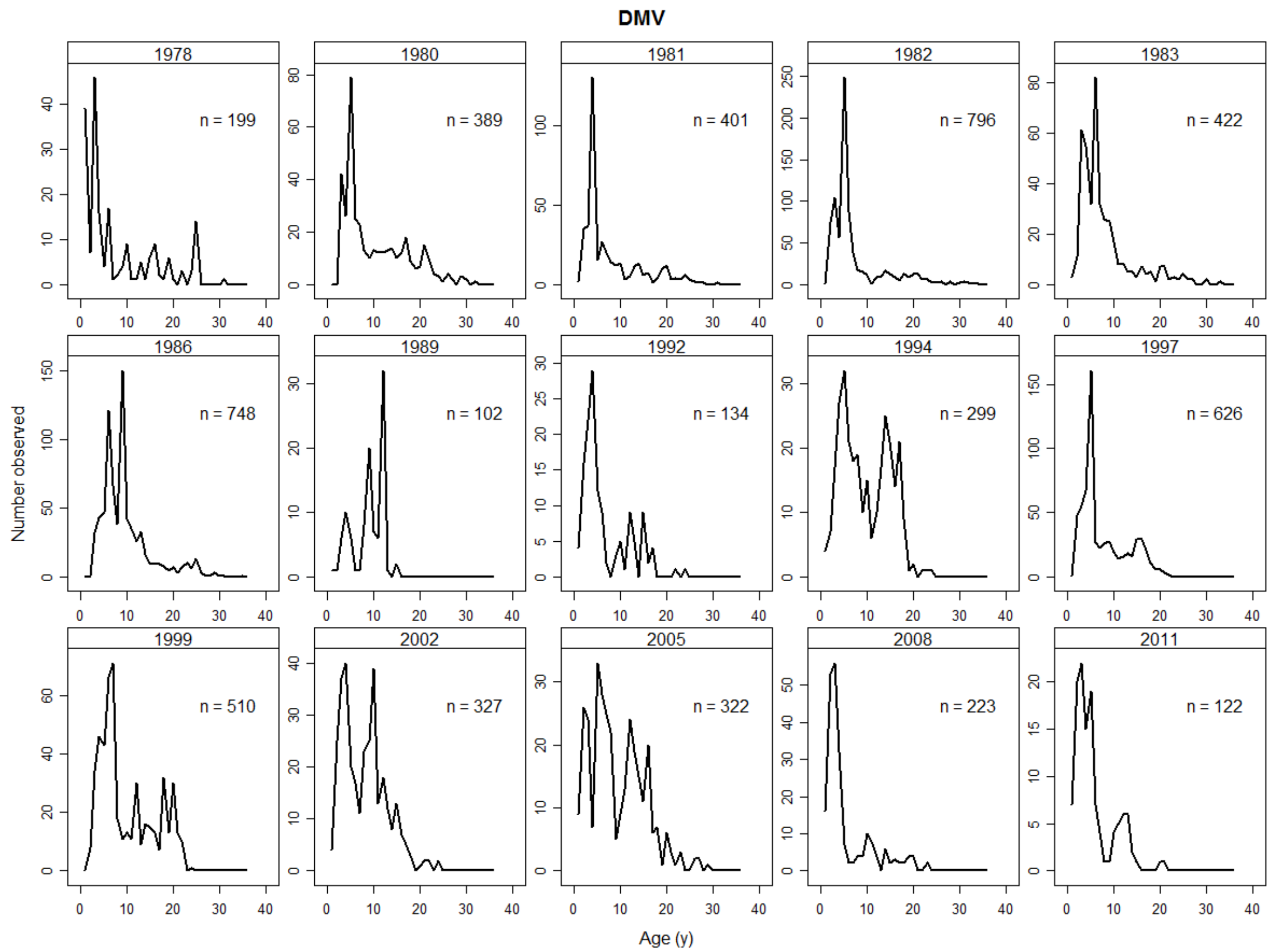


Figure A32. Age composition of NEFSC surveys in DMV.

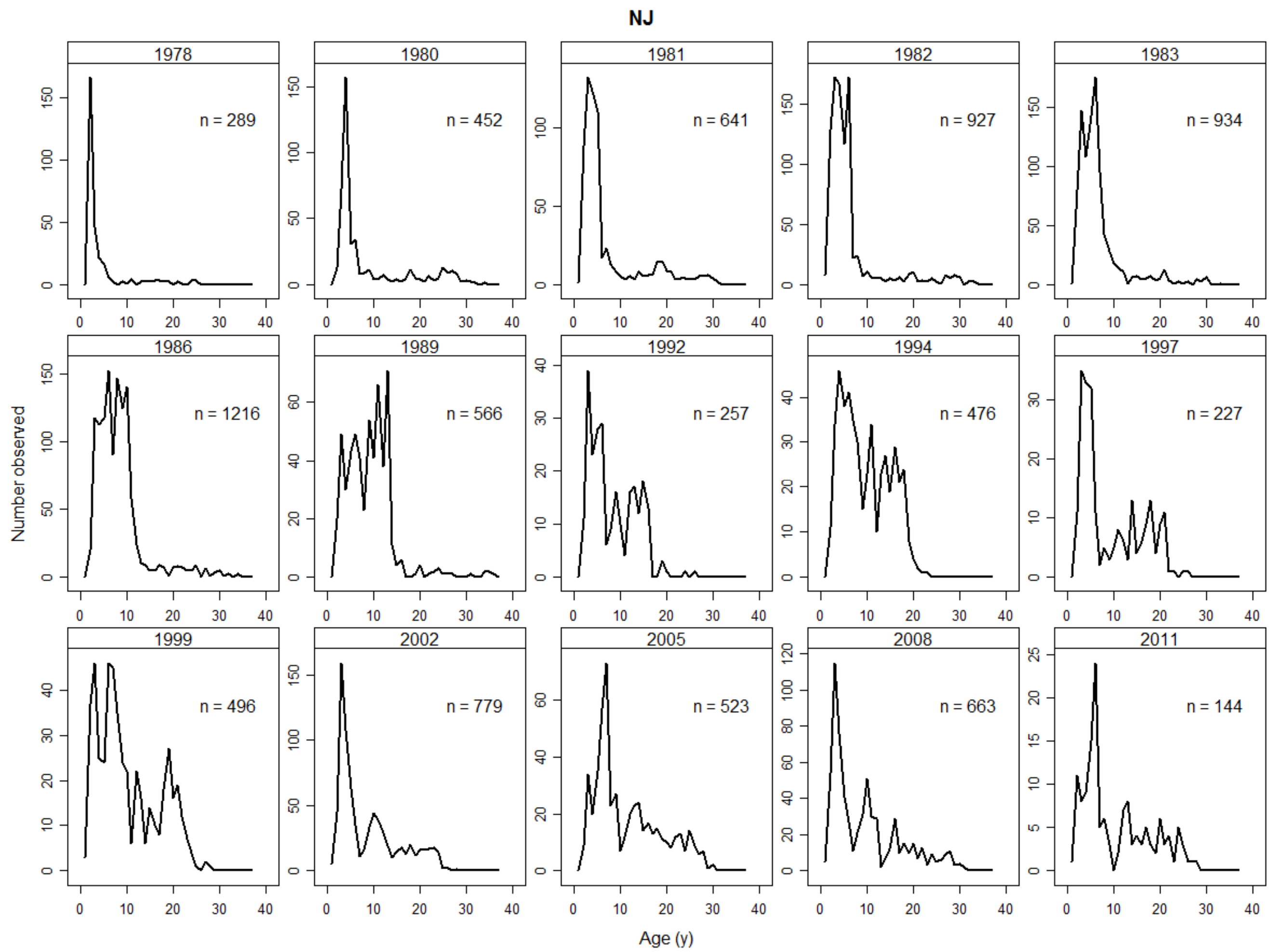


Figure A33. Age composition of NEFSC surveys in NJ.

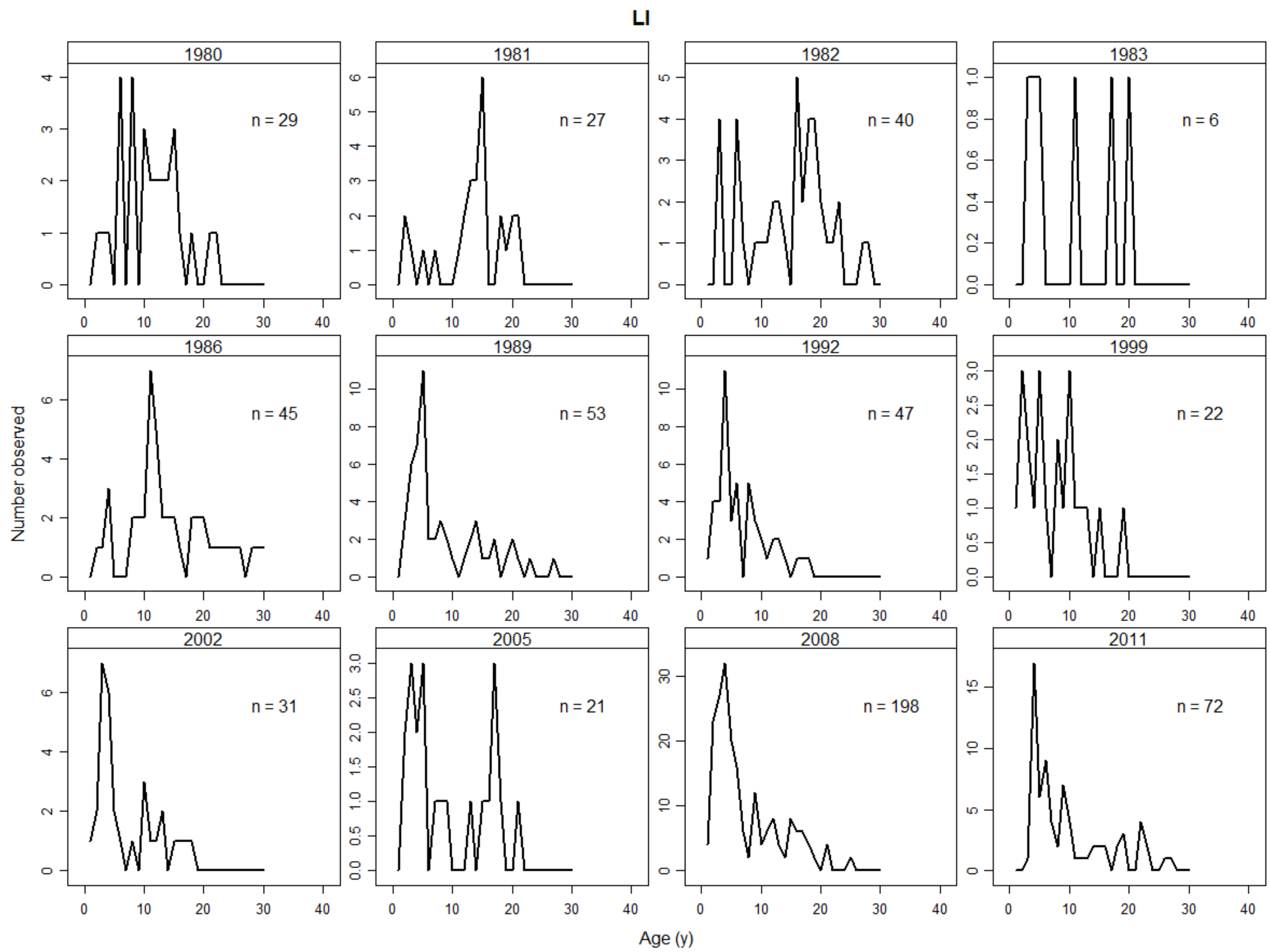


Figure A34. Age composition of NEFSC surveys in LI.

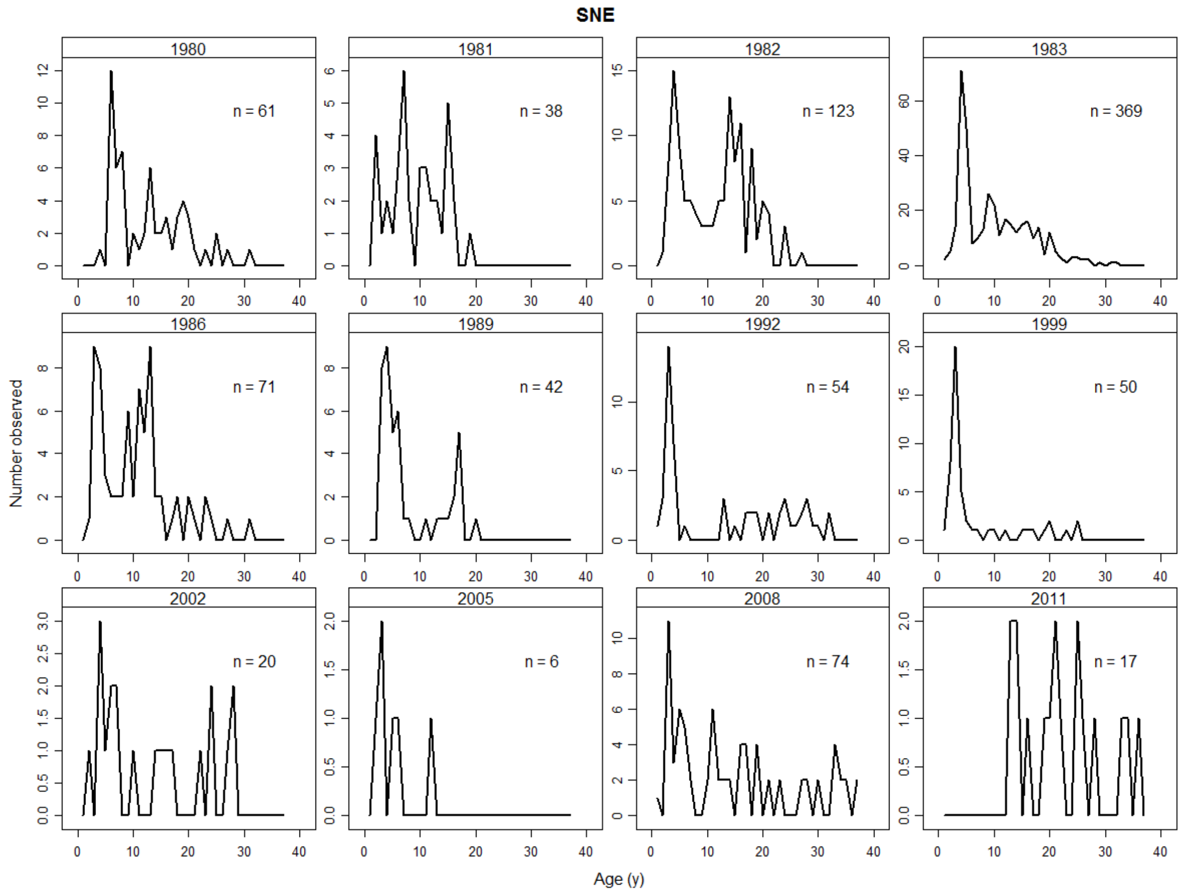


Figure A35. Age composition of NEFSC surveys in SNE.

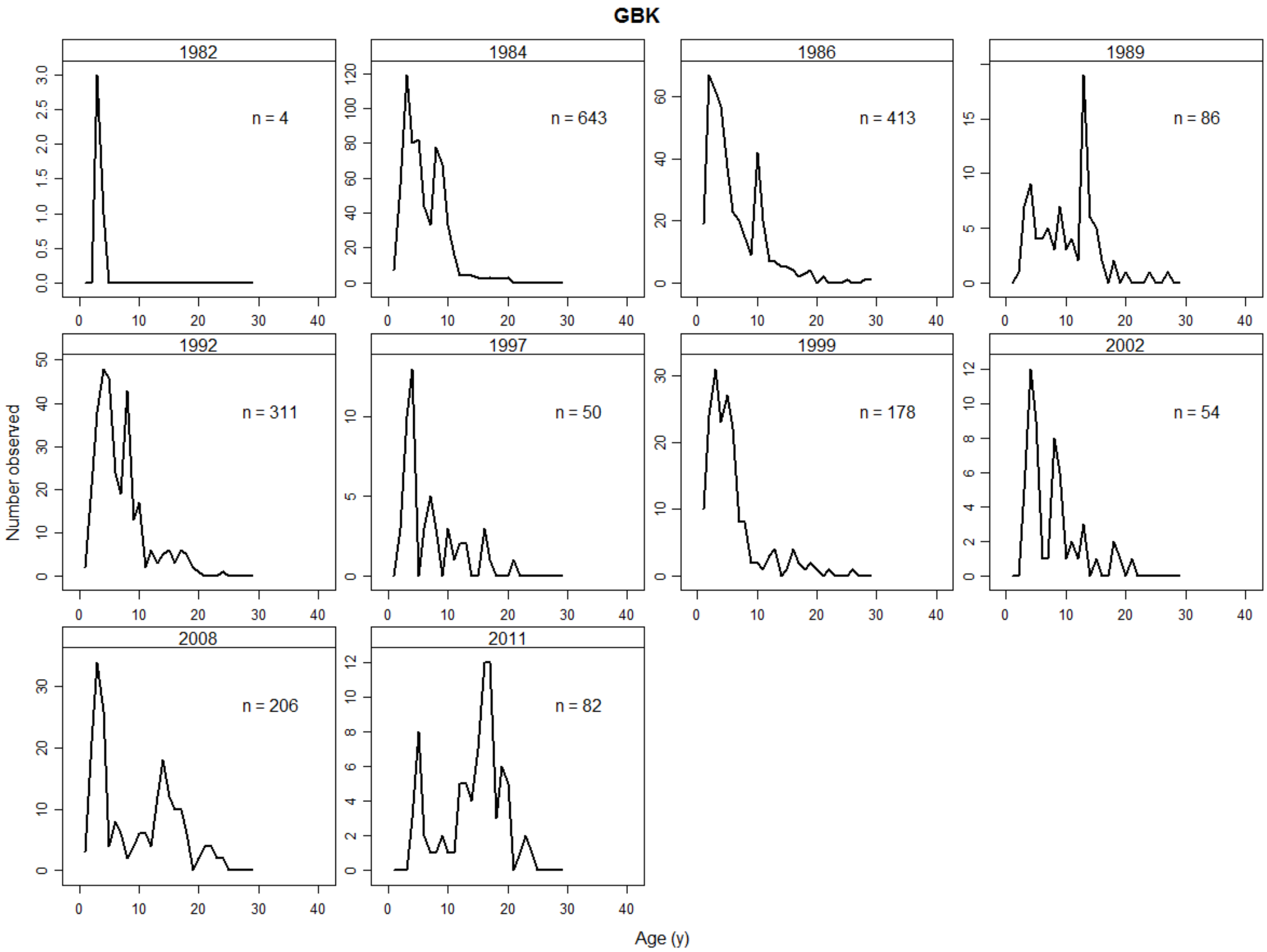
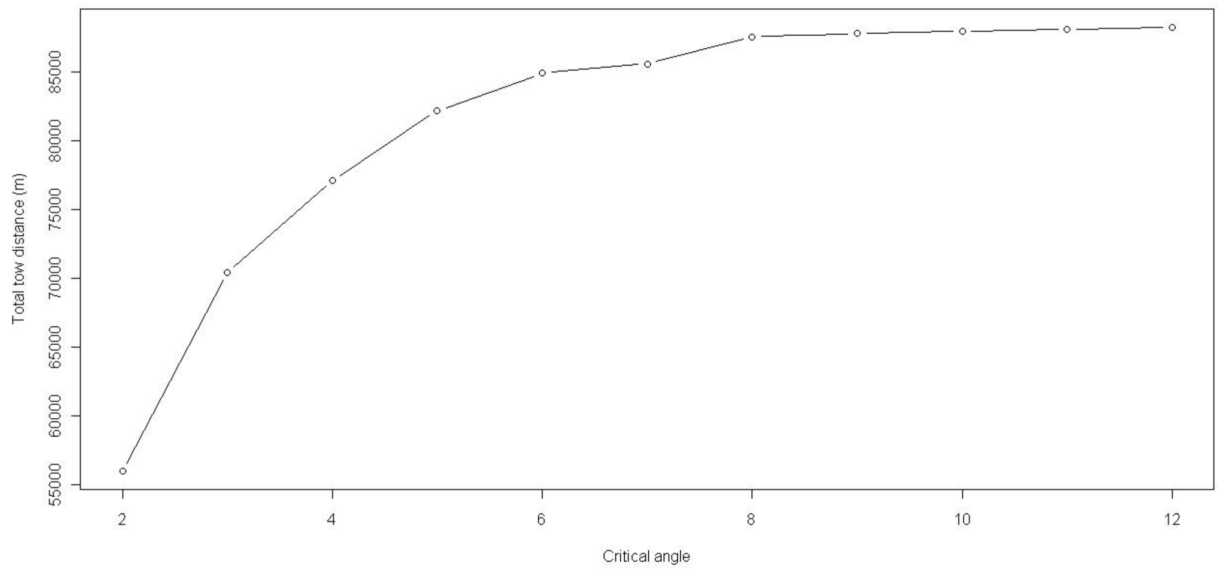


Figure A36. Age composition of NEFSC surveys in GBK.



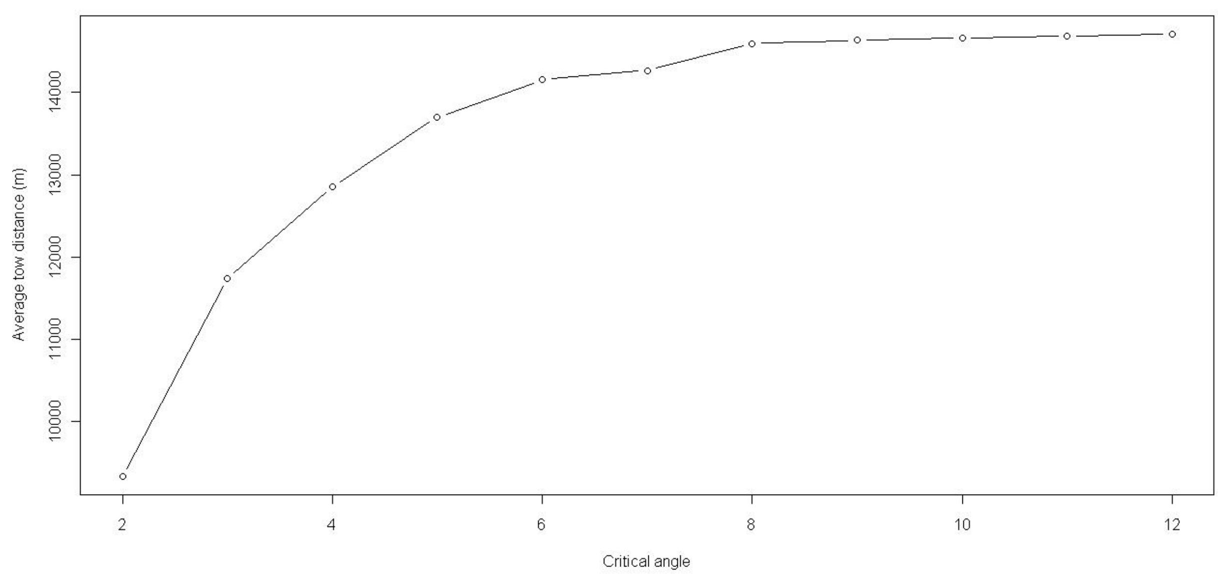
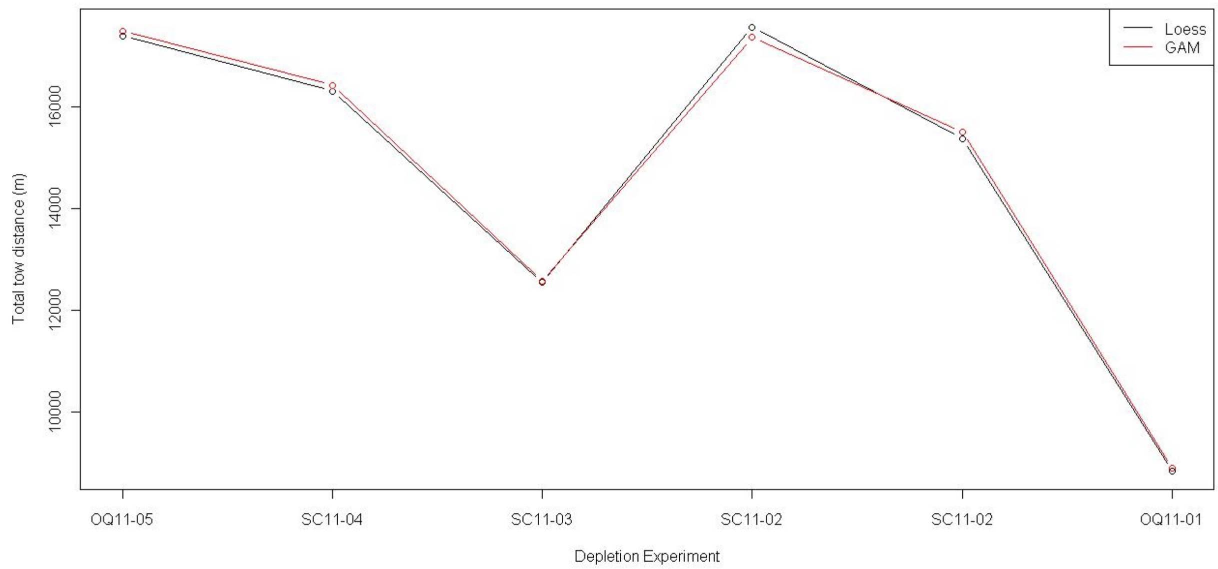


Figure A37. Total and average tow distance across all depletion experiments conducted in 2011 by the critical angle measured by the inclinometer and used to determine if the dredge was actively fishing. A larger critical angle results in more time fishing. The curve appears to asymptote at approximately 8 degrees and any critical angle between 8 and 12 degrees will produce approximately the same total and average tow distance.



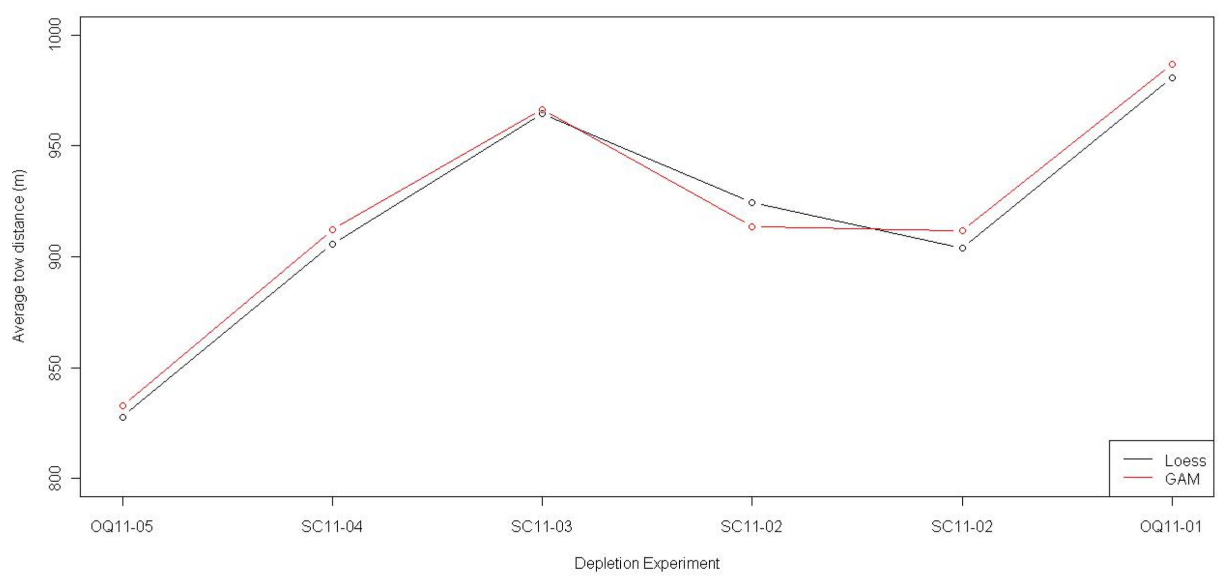


Figure A38. The total and average tow distance across all tows within each depletion experiment (including to Ocean quahog experiments) calculated using two common smoothing algorithms: loess and GAM splines. The choice of smoother did not appear to bias tow distance systematically.

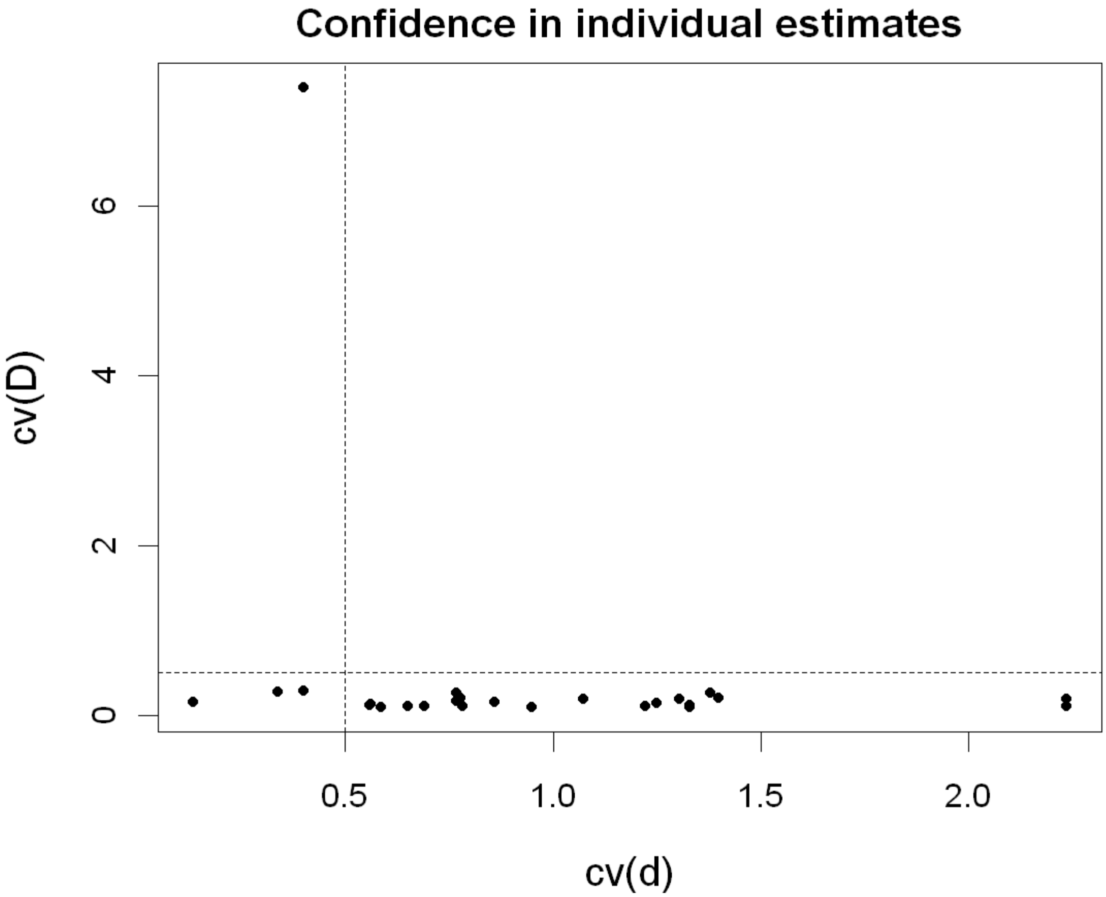


Figure A39. A comparison of the relative confidence in the components of the ratio used to estimate dredge efficiency. *D* is the density estimated in depletion experiments using the Patch model, while *d* is the density estimated using the set ups tows. The variability in *d* is relatively high compared to the variability in *D*. The dotted lines are for reference and represent a CV = 0.5 for each component.

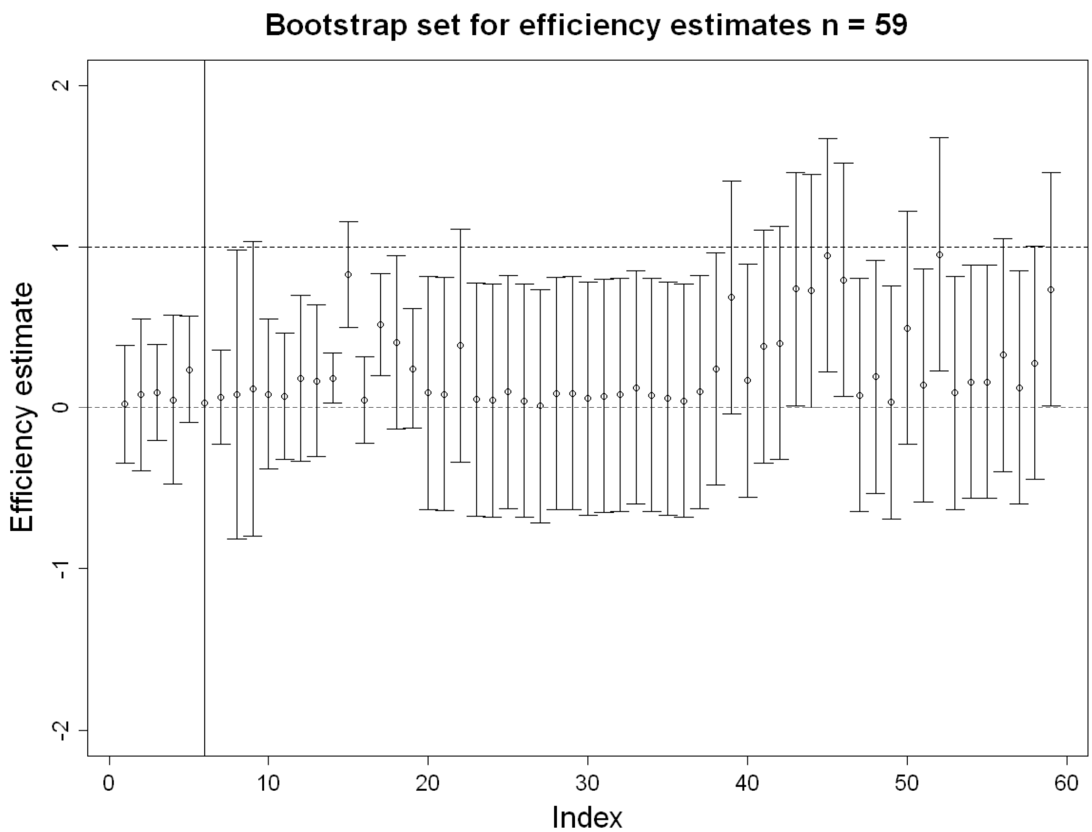


Figure A40. The set of prior knowledge for dredge efficiency estimates. Each individual estimate is shown with an error bar representing the magnitude of its CV.

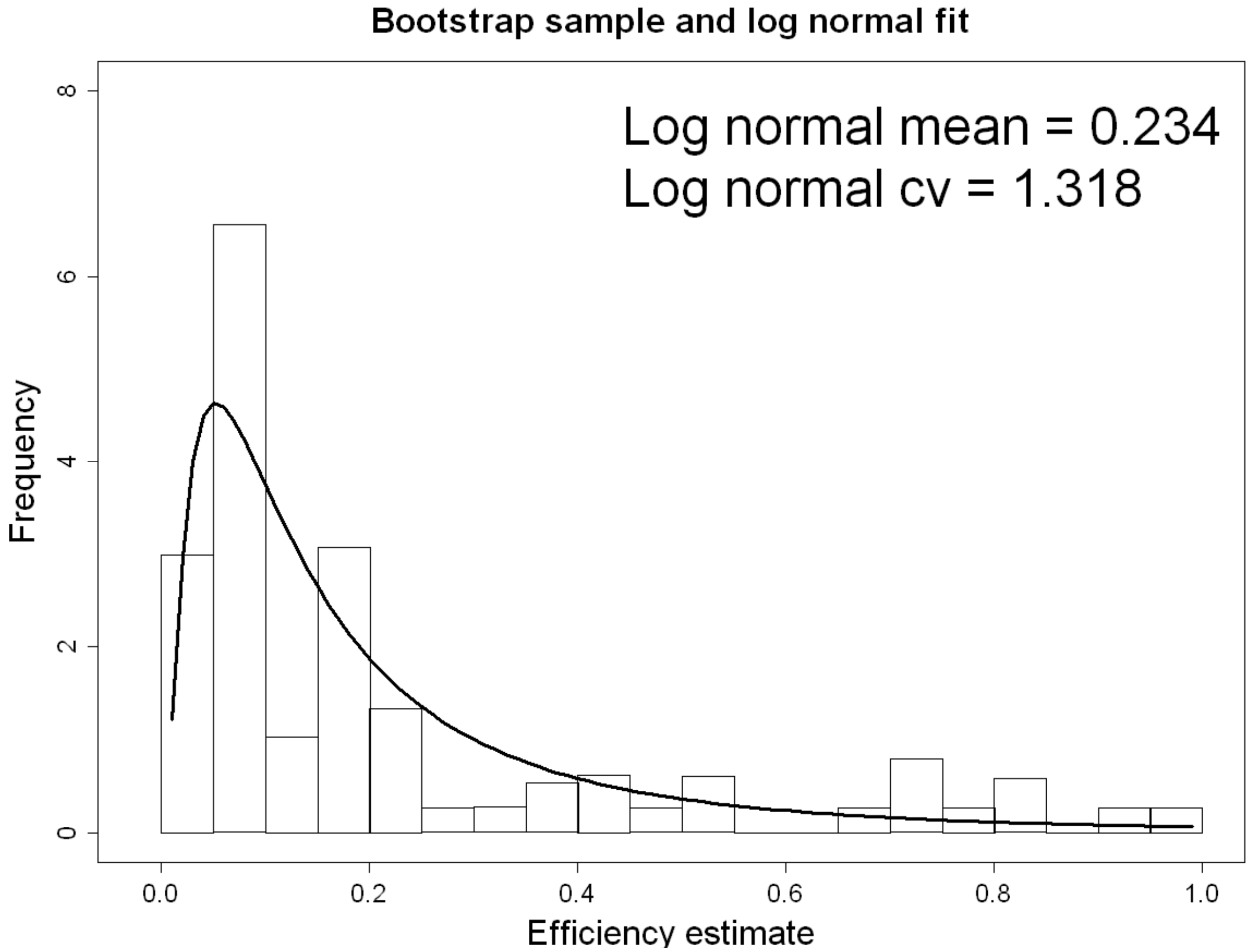


Figure A41. Bootstrapped data set and log normal fit. The distribution shown here is the prior distribution for survey dredge efficiency used in the assessment.

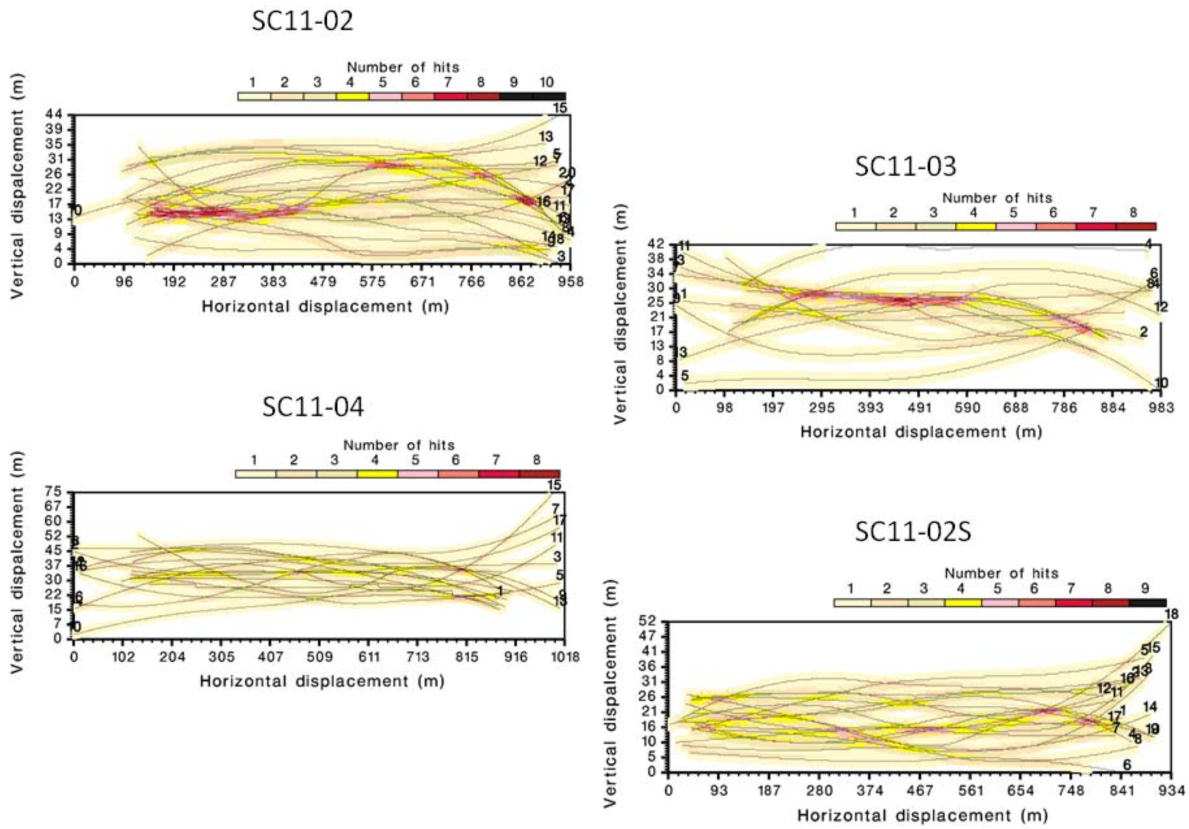


Figure A42. Maps of the tow sequence for all surfclam depletion experiments conducted in 2011.

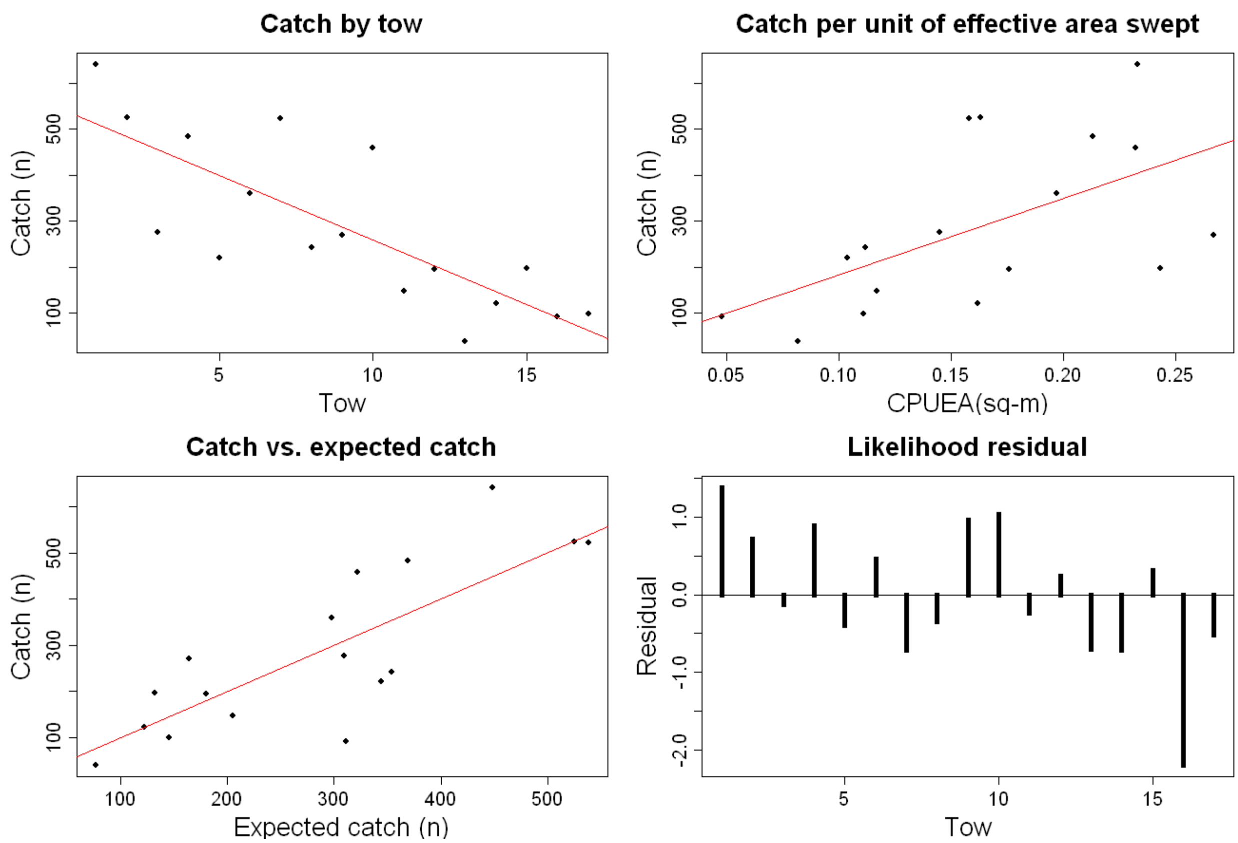


Figure A43. Patch model diagnostics for depletion experiment SC11-04. These include: catch by tow, catch per unit of effective area swept, catch vs. expected catch and the likelihood residuals from the patch model fit. Effective area swept accounts for the proportion of ground that is being repeatedly fished for the first, second, third, etc... overlapping tow. The expected catch is the catch predicted by the Patch model.

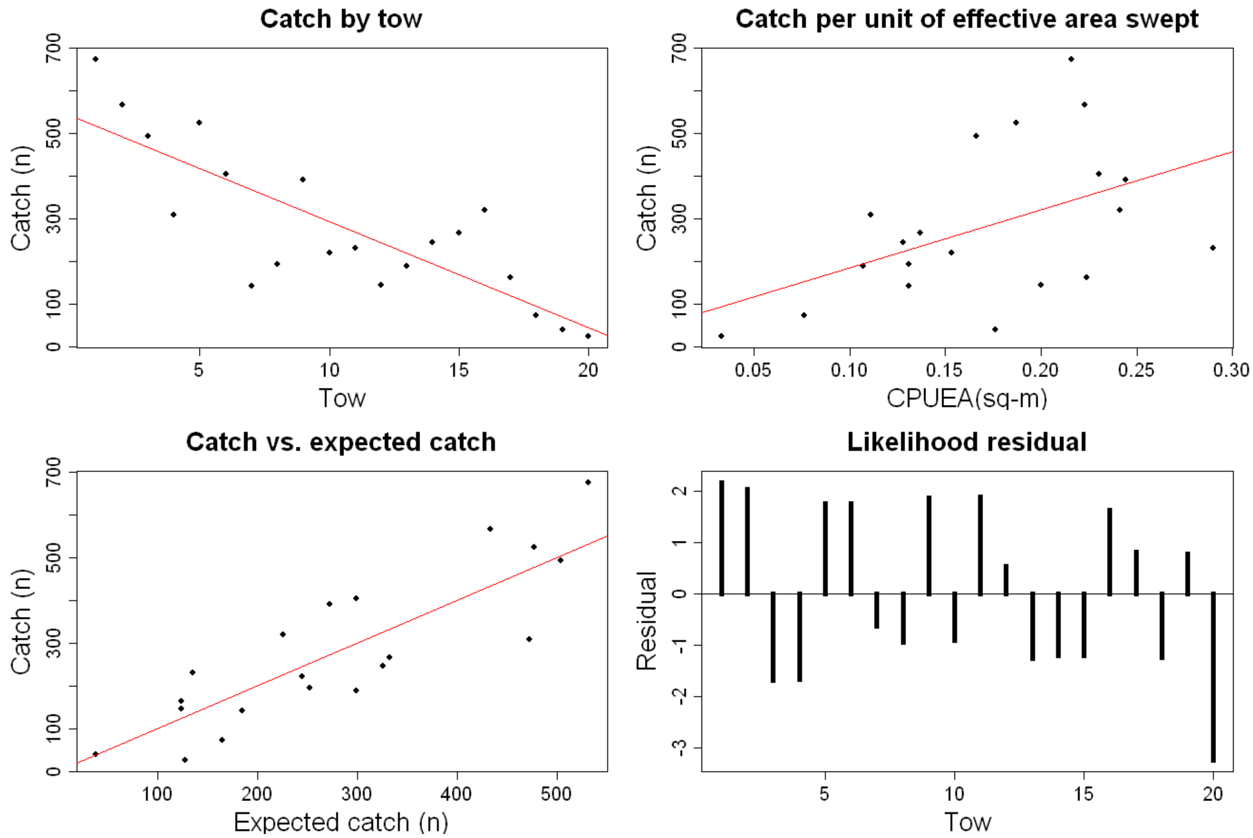


Figure A44. Patch model diagnostics for SC11-02.

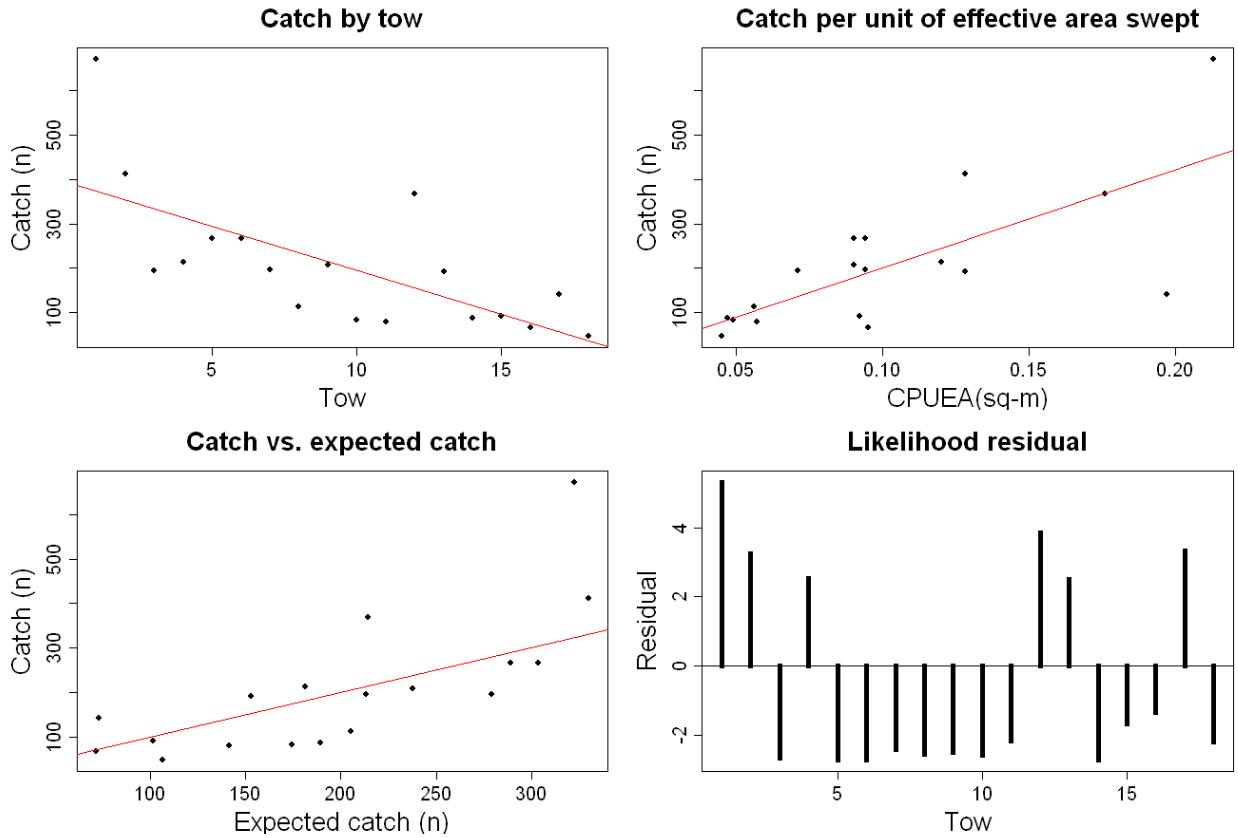


Figure A45. Patch model diagnostics for SC11-02S.

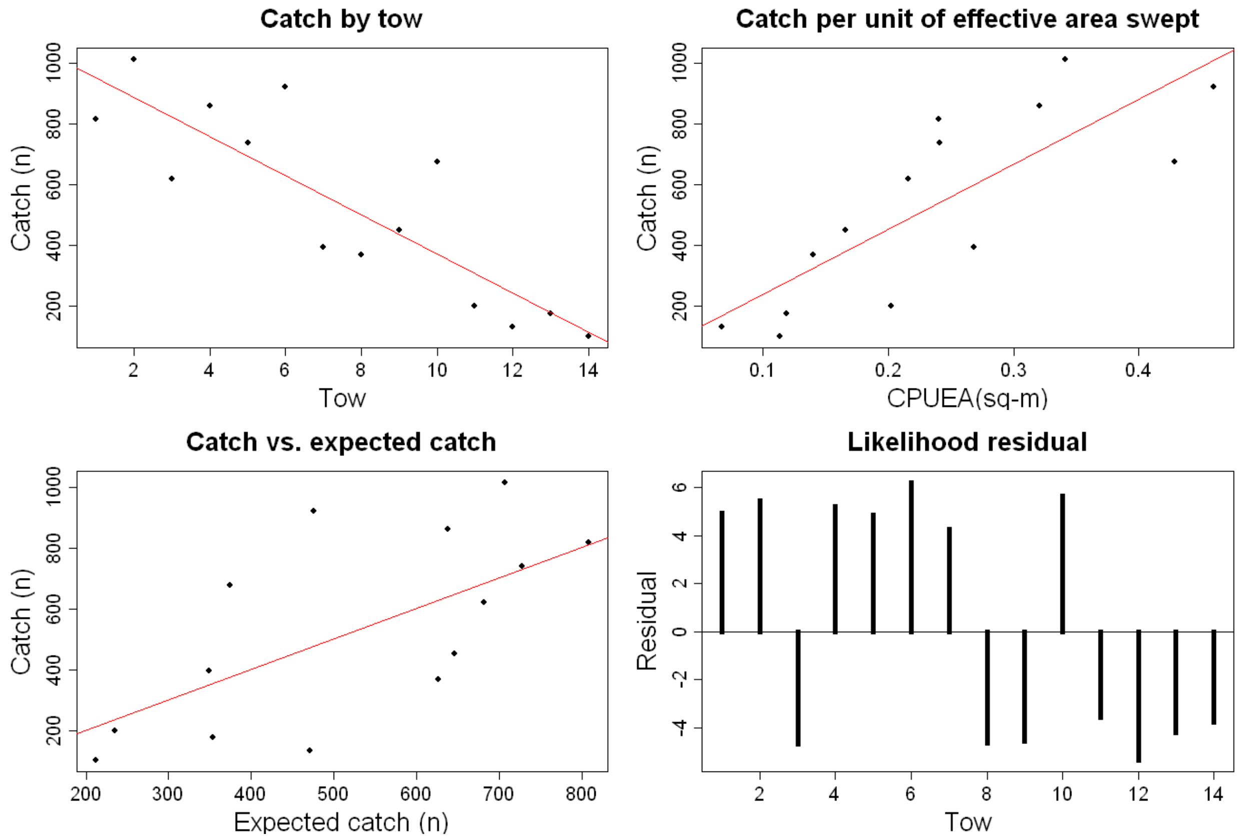


Figure A46. Patch model diagnostics for SC11-03.

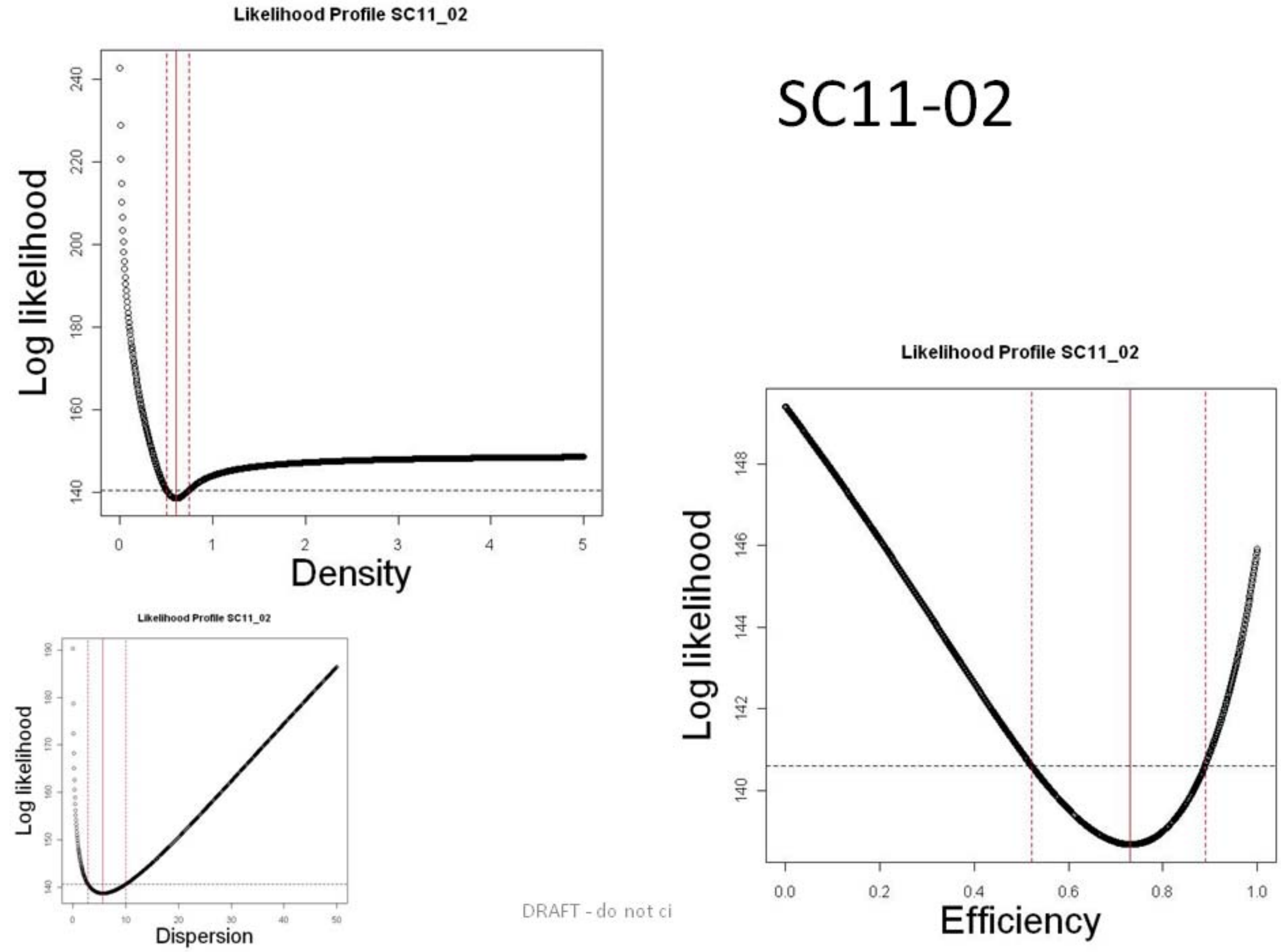


Figure A47. Likelihood profiles for SC11-02. The red lines are the estimates and delta method approximate 95% confidence intervals.

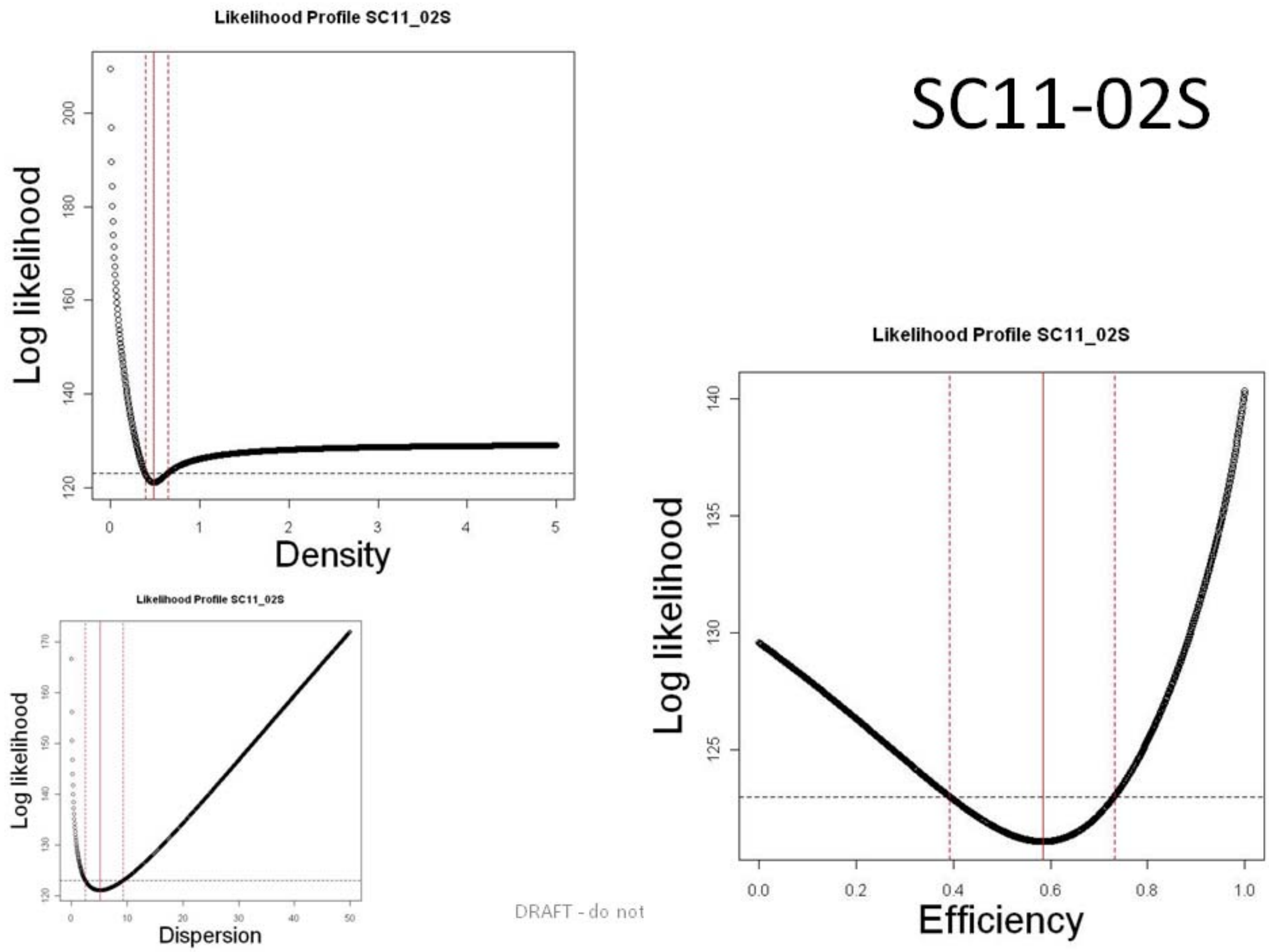


Figure A48. Likelihood profiles for SC11-02S.

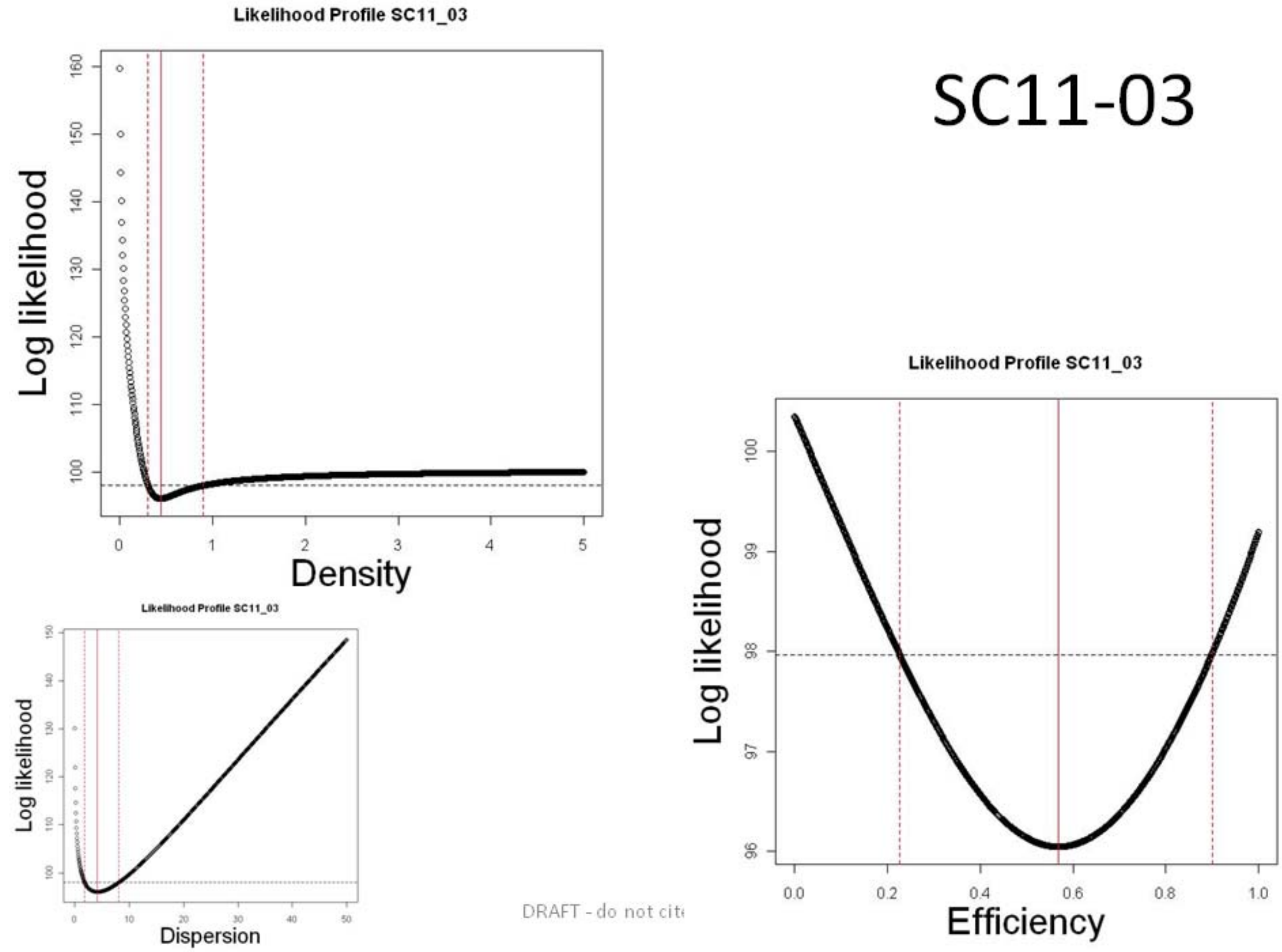


Figure A49. Likelihood profiles for SC11-03.

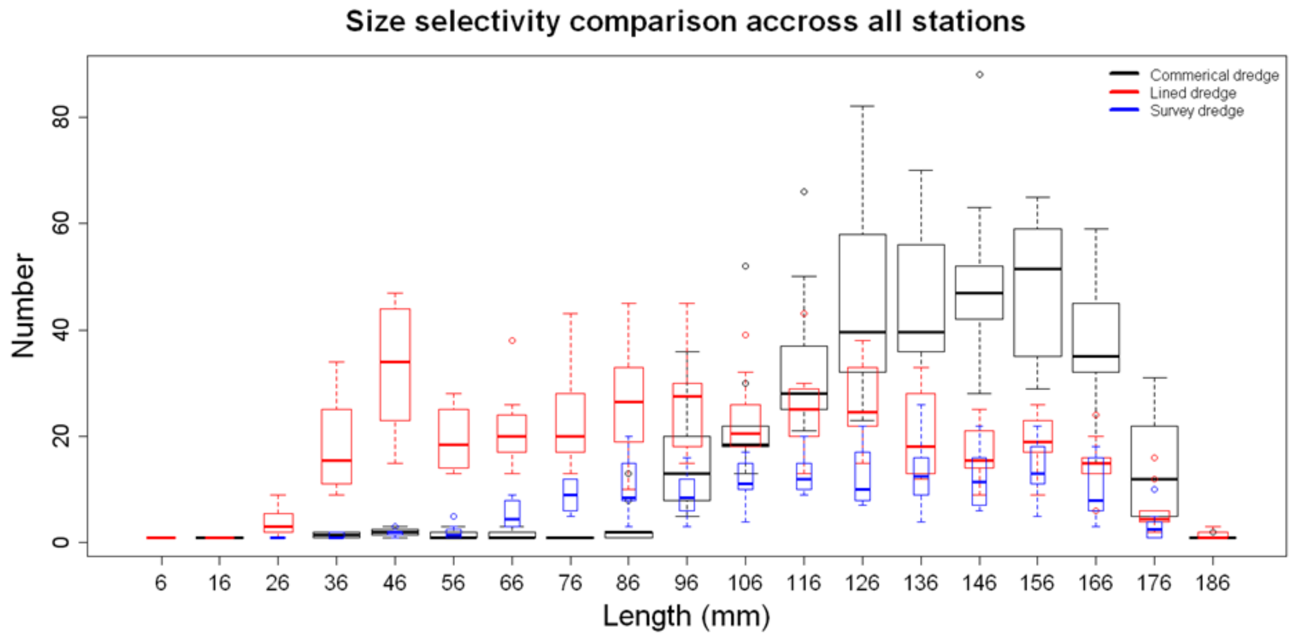


Figure A50. Surfclam shell height composition data used to estimate selectivity of the NEFSC survey clam dredge. Summarized here using 1 cm bins.

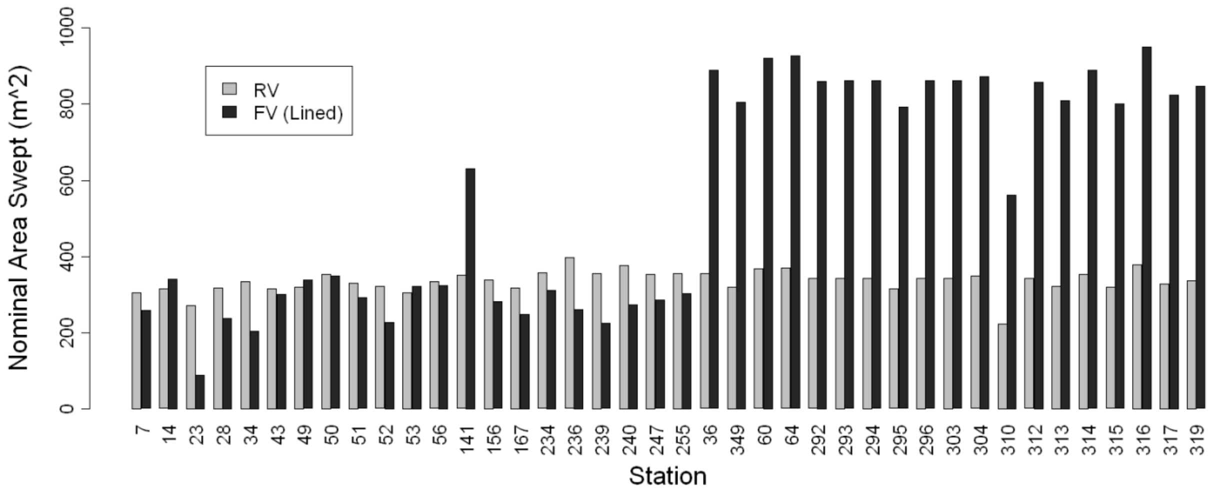


Figure A51. Swept area comparison at each station in survey selectivity experiments in 2008 and 2011.

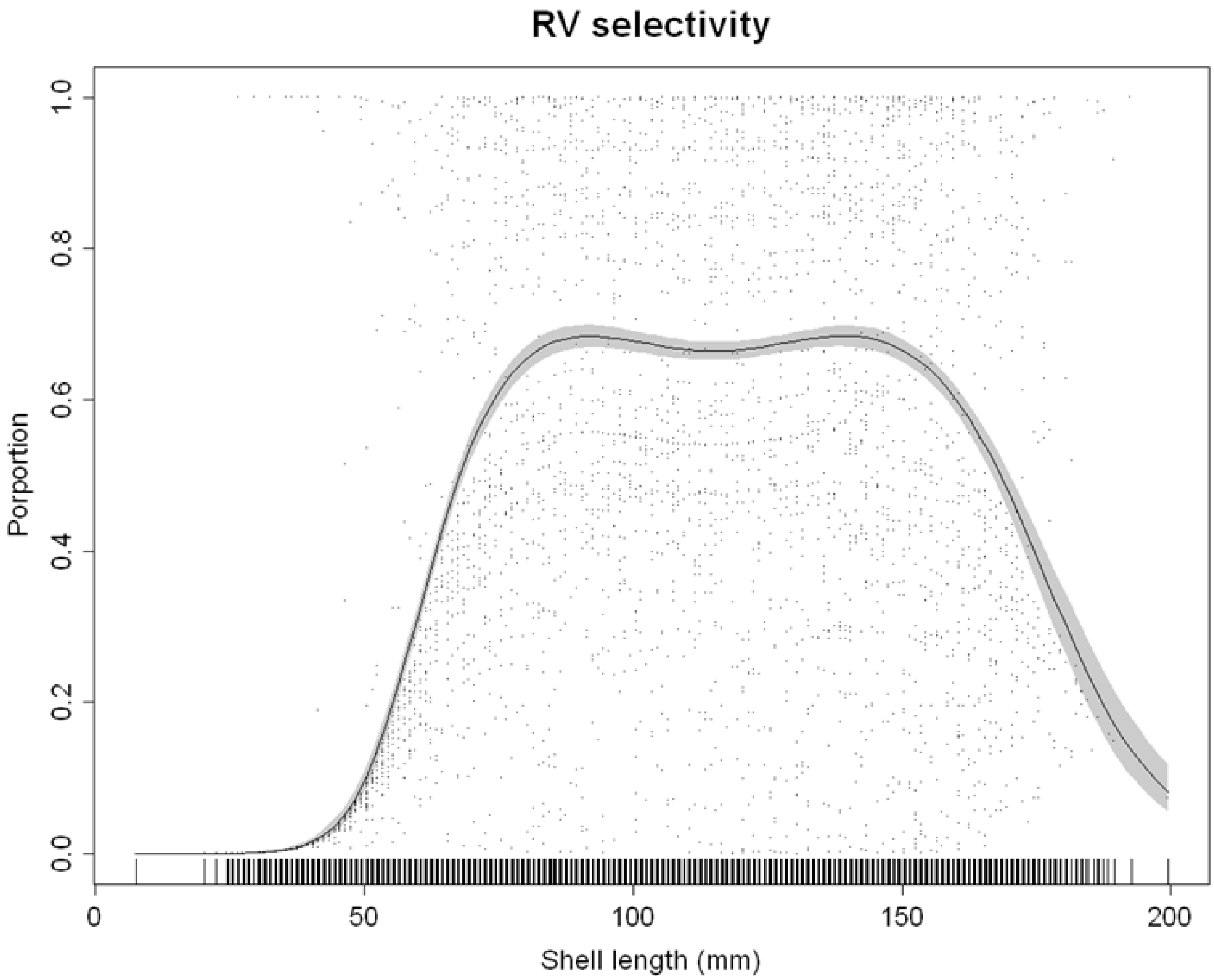


Figure A52. GAM model fit to selectivity data. The dots are the residuals, the gray band is the +/- 2 standard error confidence interval, and the rug plot above the x axis indicate data density (weights). Much of the variance shown is eliminated in modeling by the offset term which adjust for differences in area swept and the overall proportion of samples in the test gear.

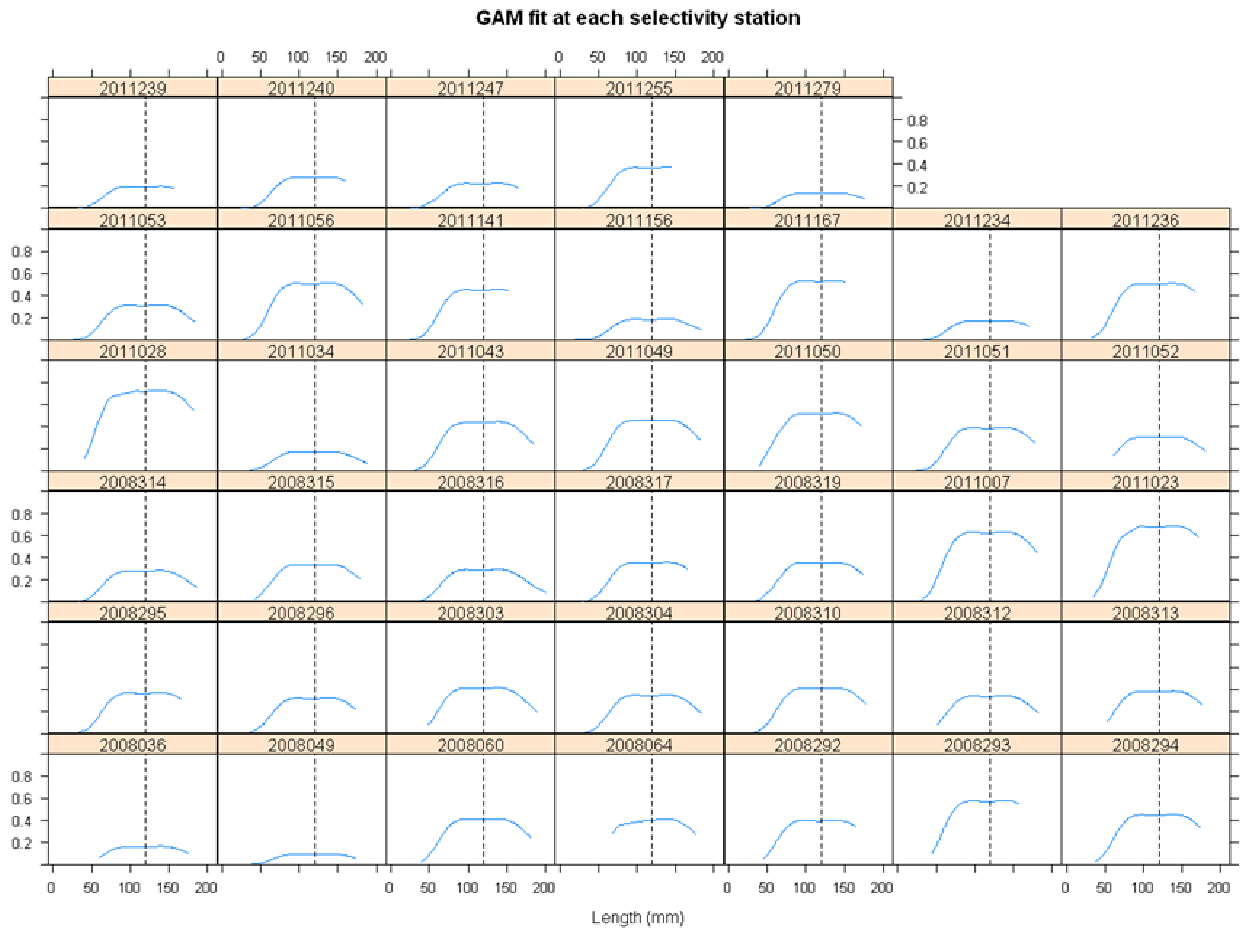


Figure A53. GAM fit at each station. This plot demonstrates that the domed shape is pervasive and not driven data from one or a few stations.

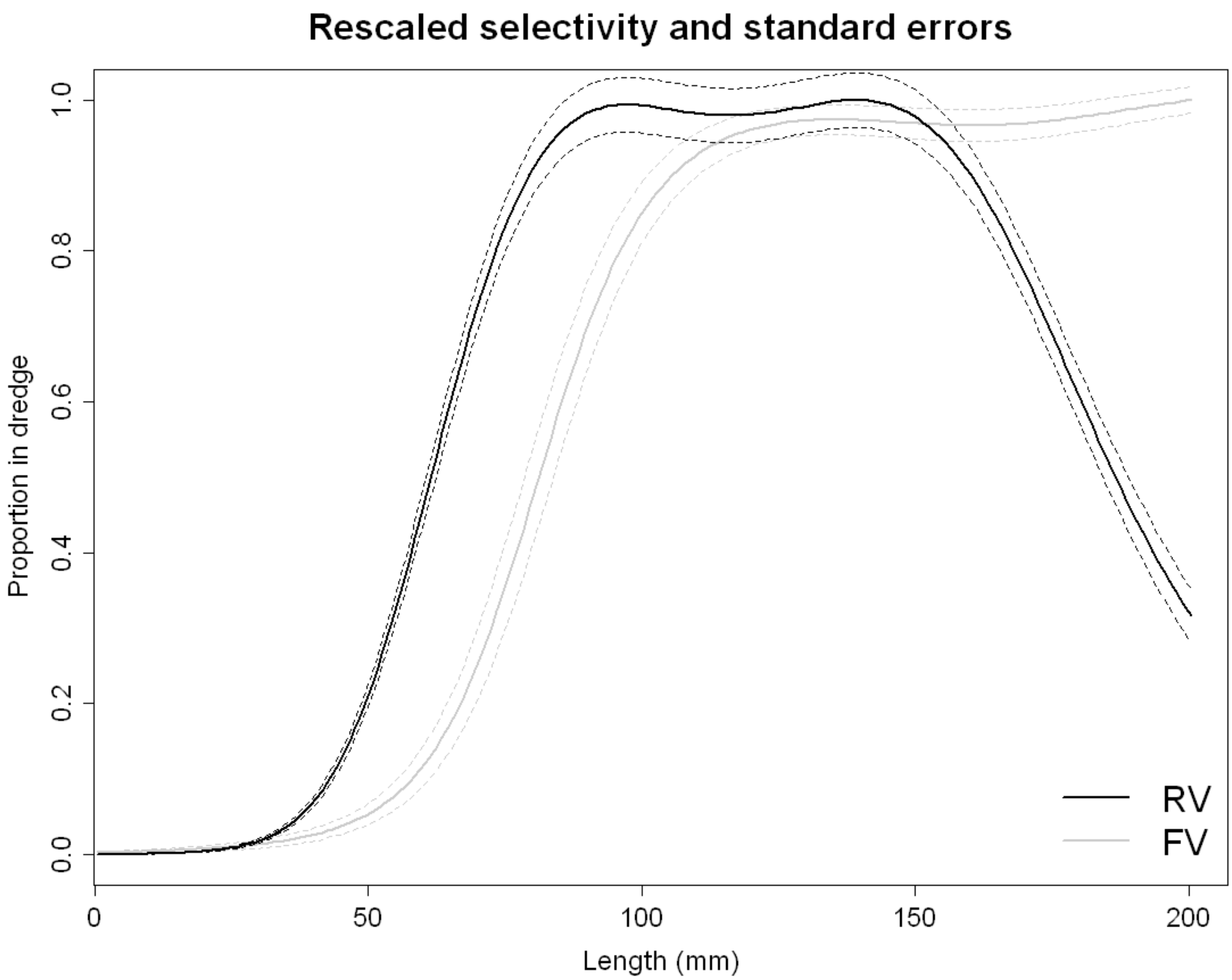


Figure A54. Rescaled selectivity fits for both survey and commercial dredges with +/- 2 standard errors.

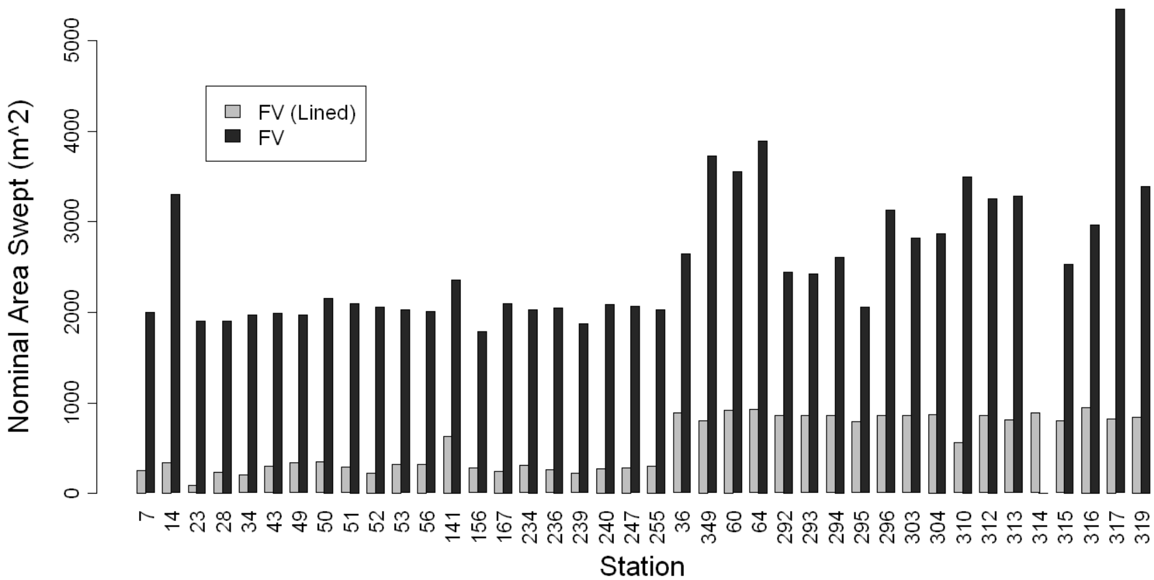


Figure A55. Swept area comparison at each station in commercial selectivity experiments in 2008 and 2011. Tow length for commercial station 314 is not available and station 314 was not used.

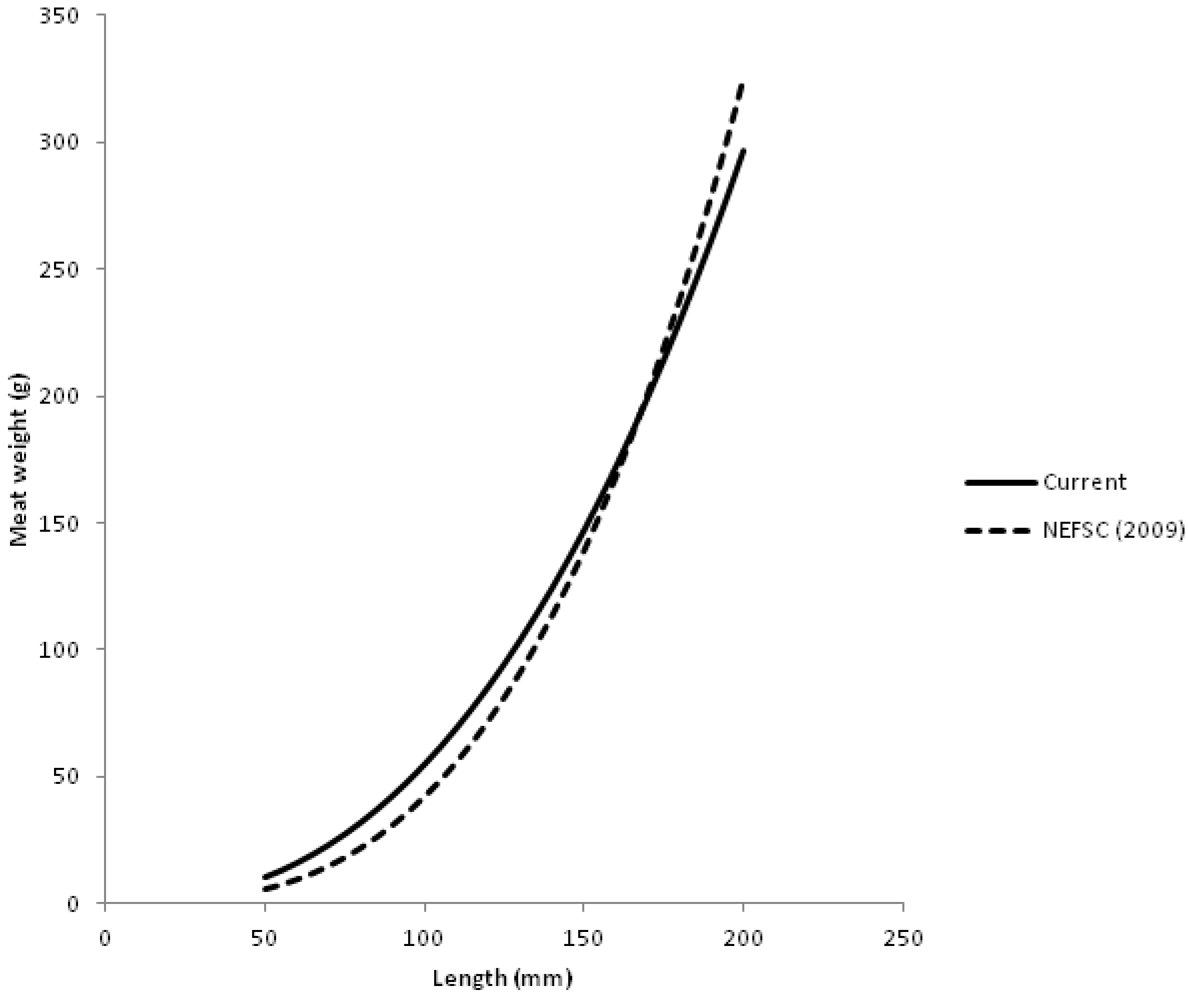


Figure A56. Length to meat weight curves from the last assessment and the current analysis. Both are based on general data, without regional or year effects. The average depth over all stations (33 m) was used to generate the curve for the current assessment in this figure.

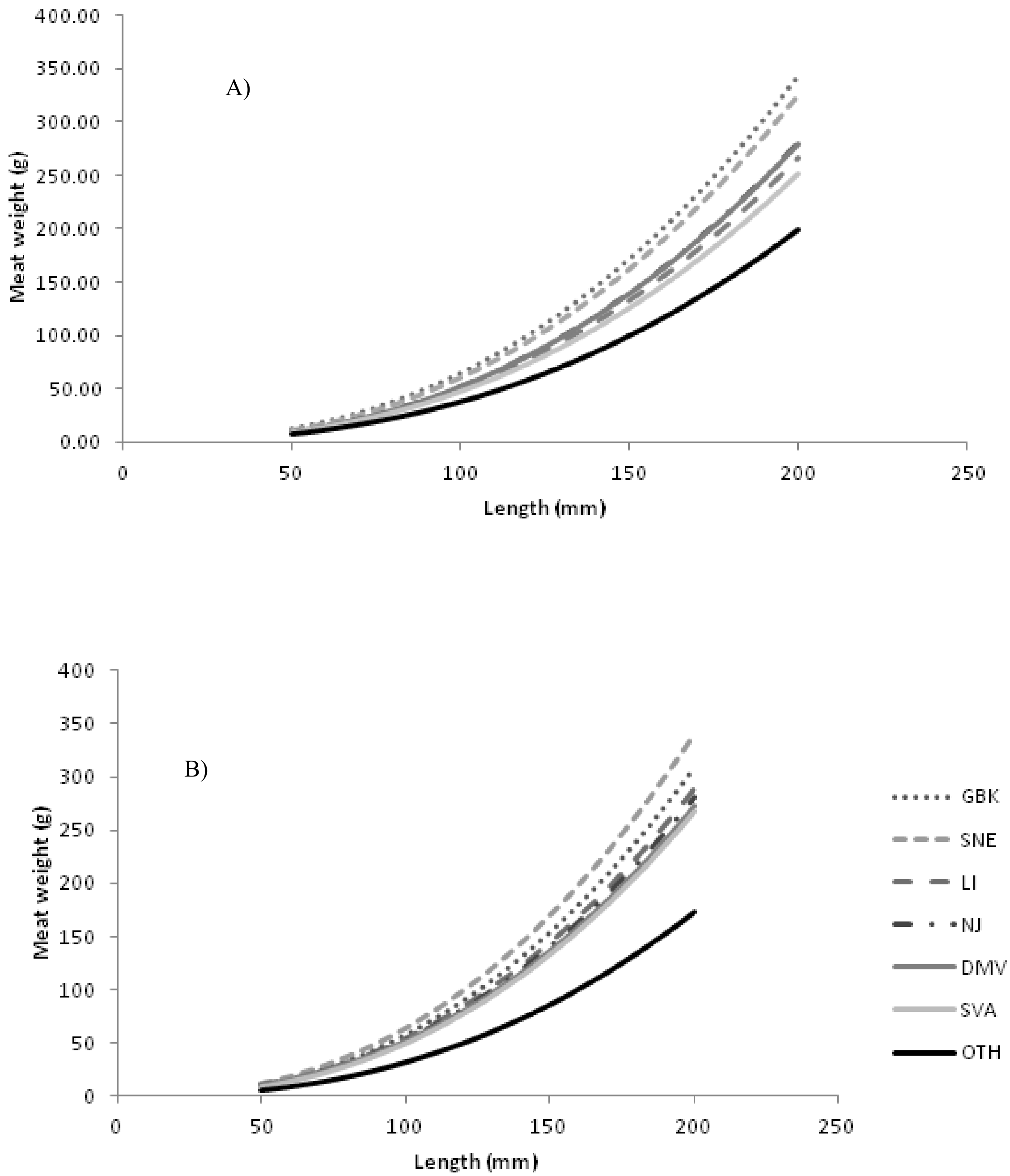


Figure A57. Regional differences in allometric relationships for surfclam. The same depth (33 m) was used to generate the curves for each region in A) and regional median depth was used to generate the curves in B).

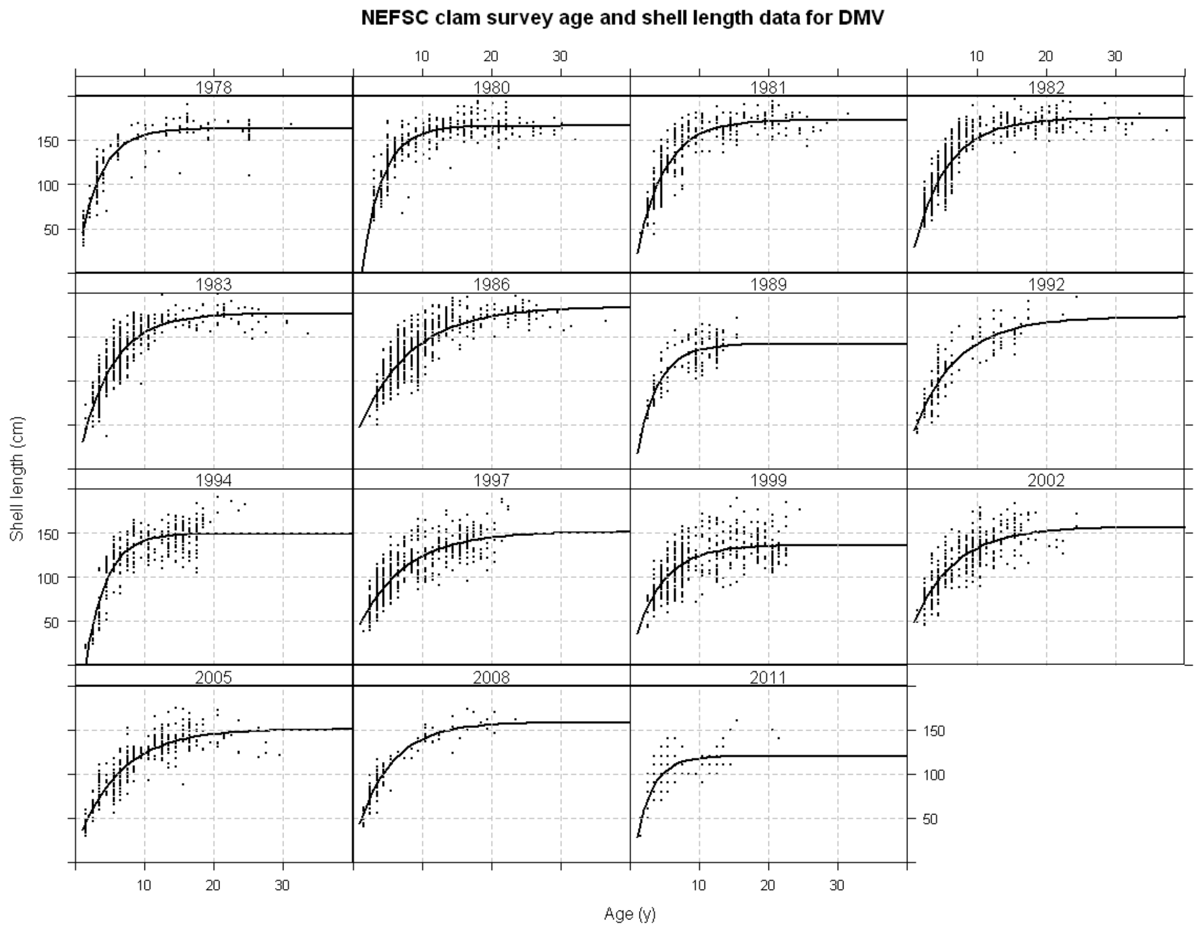


Figure A58. Age vs. length with fitted Von Bertalanffy growth curve for the DMV region in each survey year.

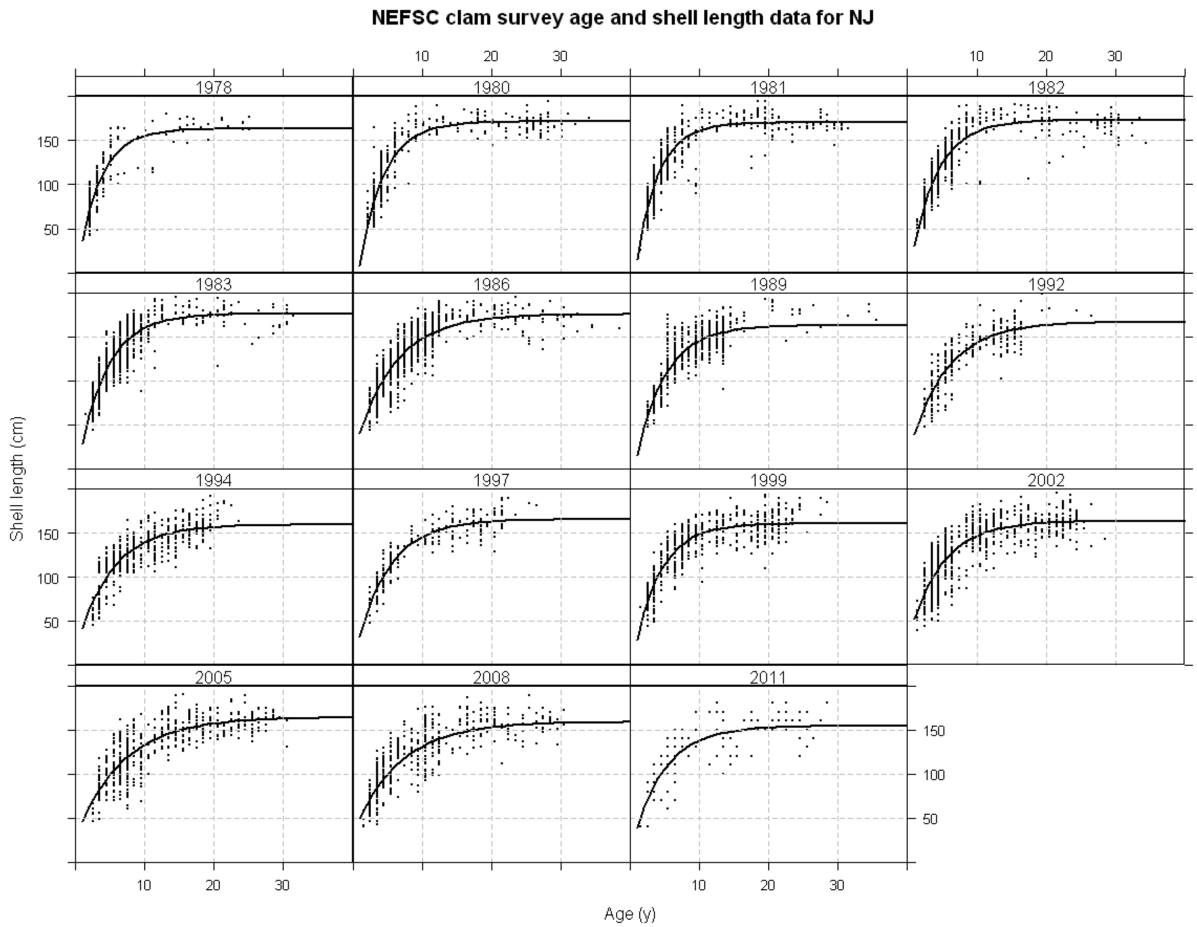


Figure A59. Age vs. length with fitted Von Bertalanffy growth curve for the NJ region in each survey year.

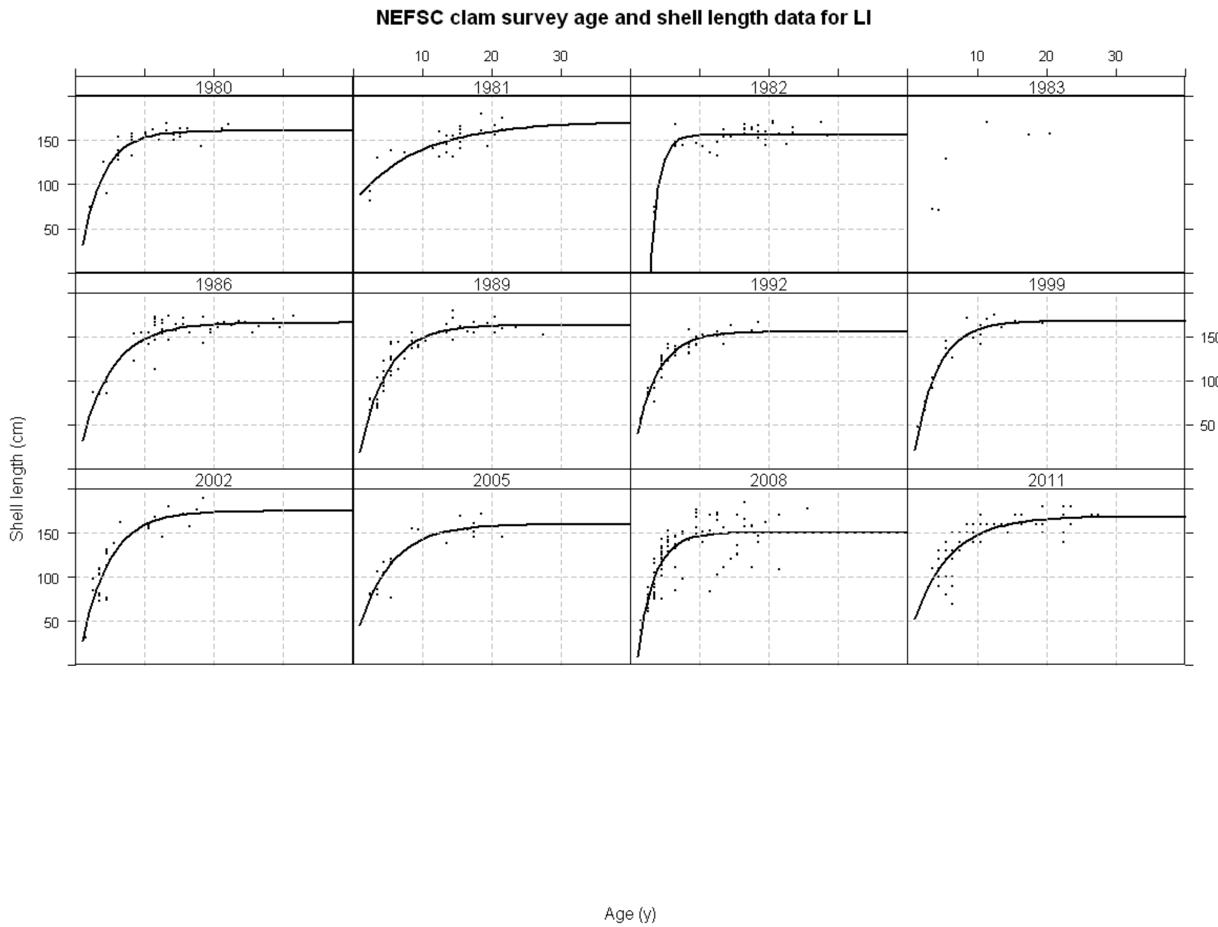


Figure A60. Age vs. length with fitted Von Bertalanffy growth curve for the LI region in each survey year.

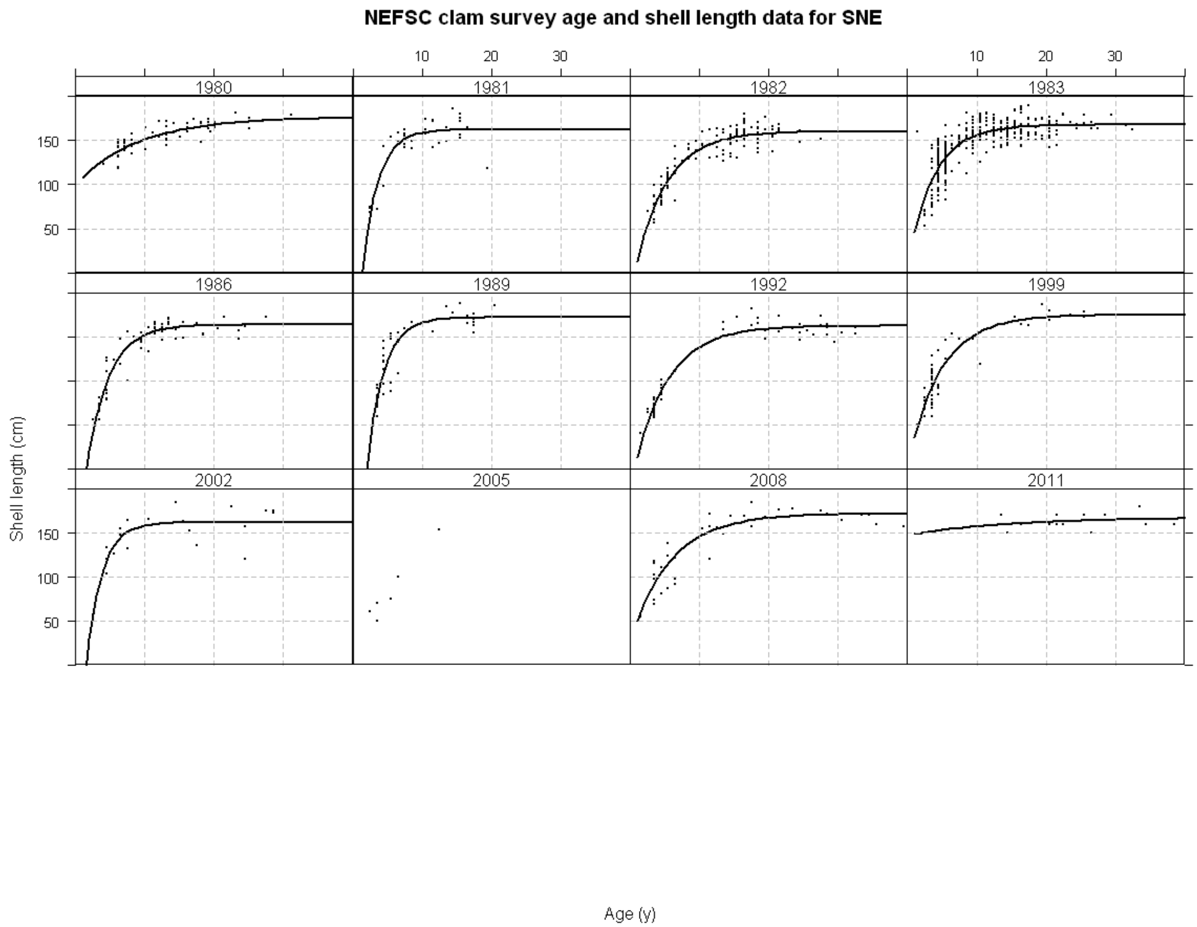


Figure A61. Age vs. length with fitted Von Bertalanffy growth curve for the SNE region in each survey year.

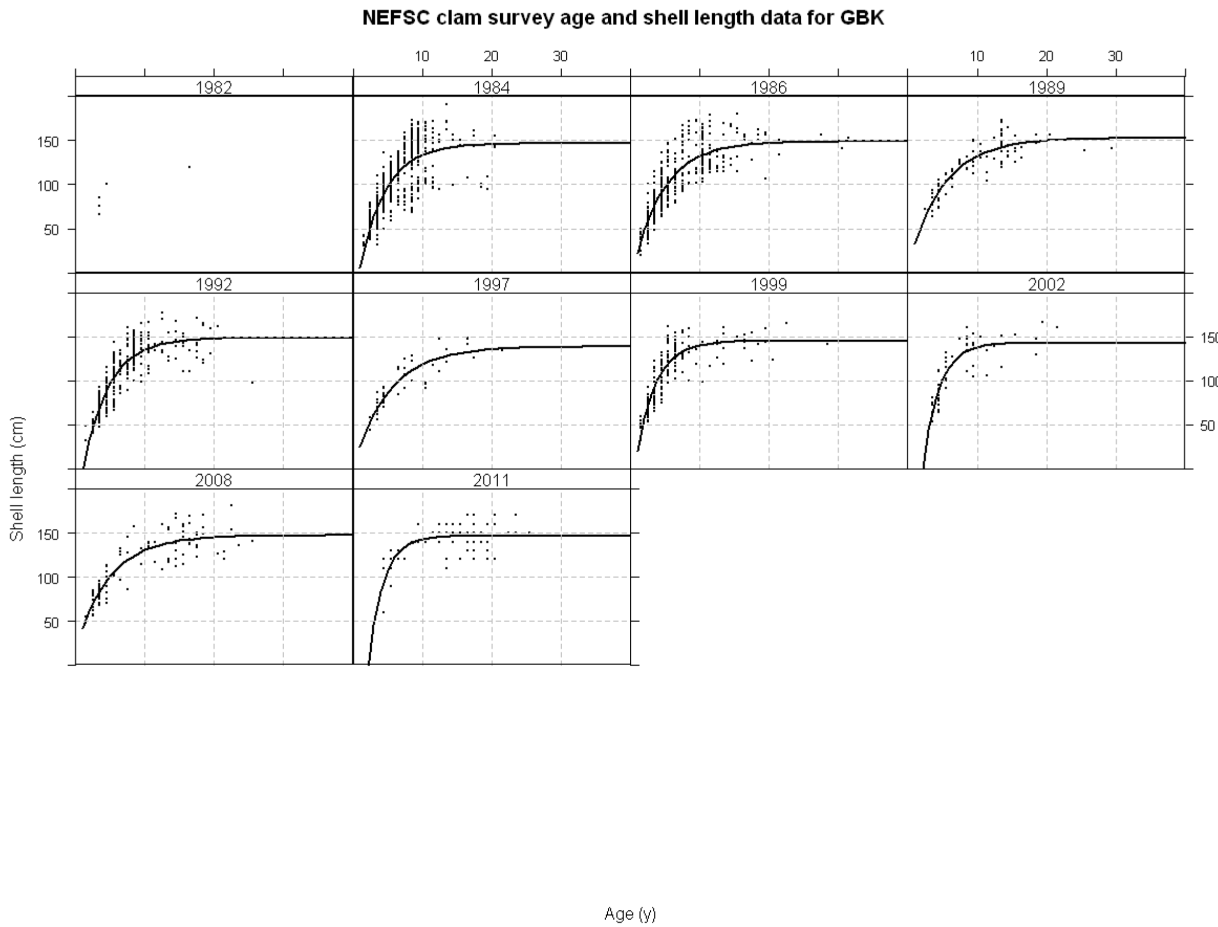


Figure A62. Age vs. length with fitted Von Bertalanffy growth curve for the GBK region in each survey year.

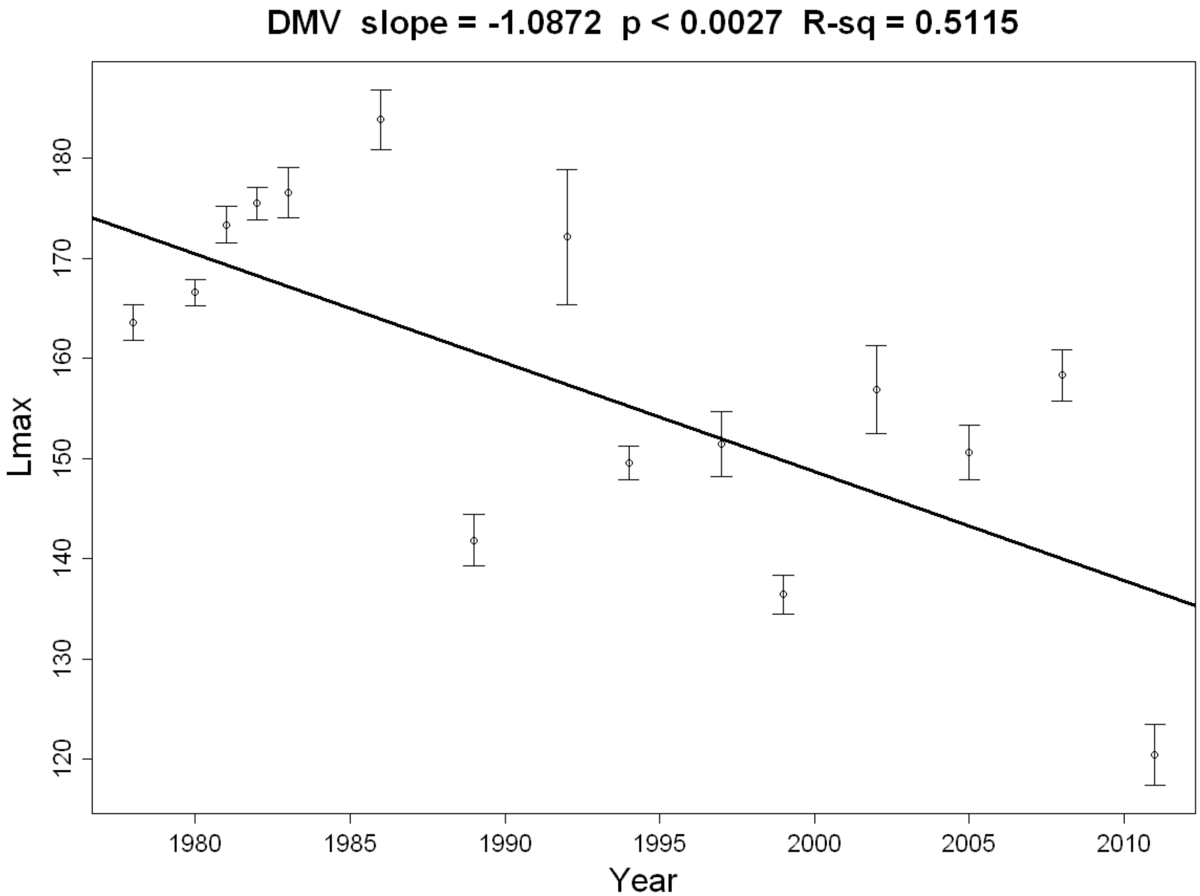


Figure A63. Weighted regression of estimated L_∞ in DMV over time.

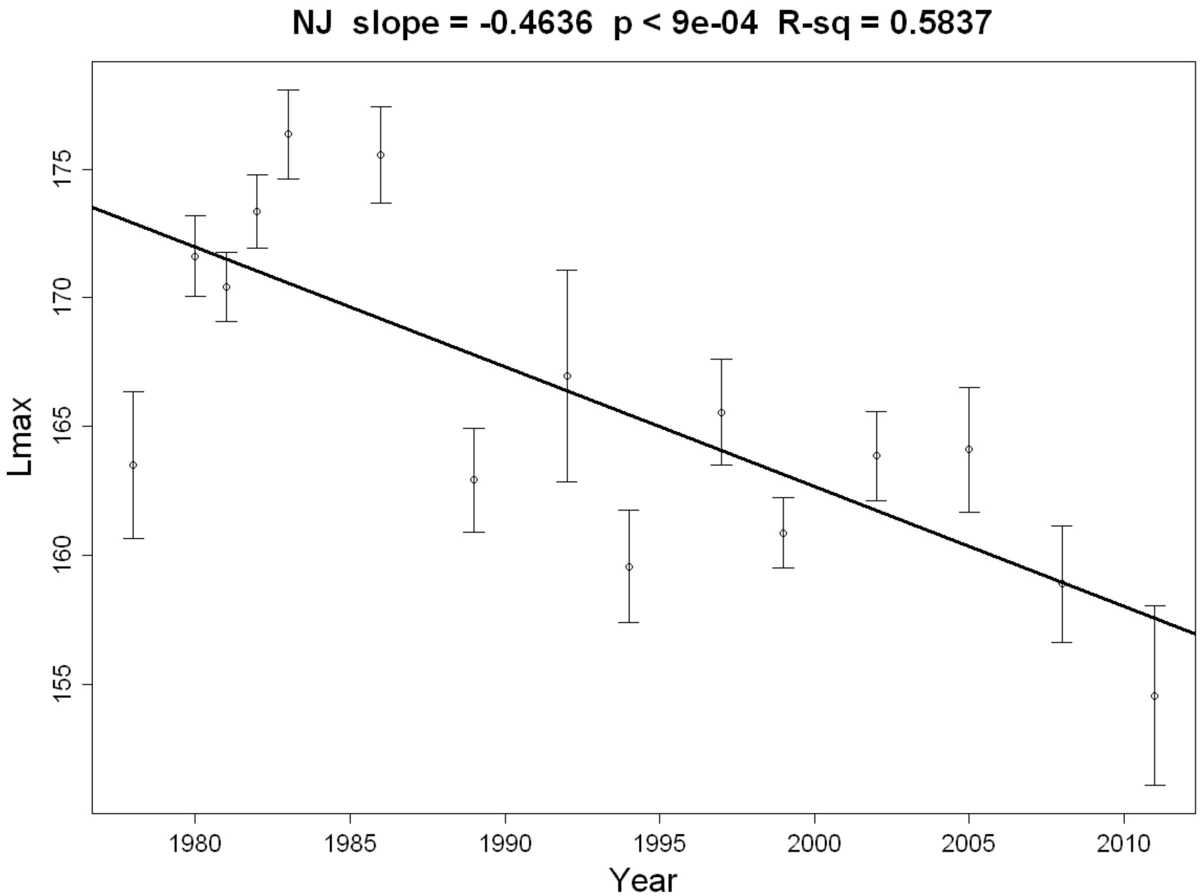


Figure A64. Weighted regression of L_∞ estimated in NJ over time.

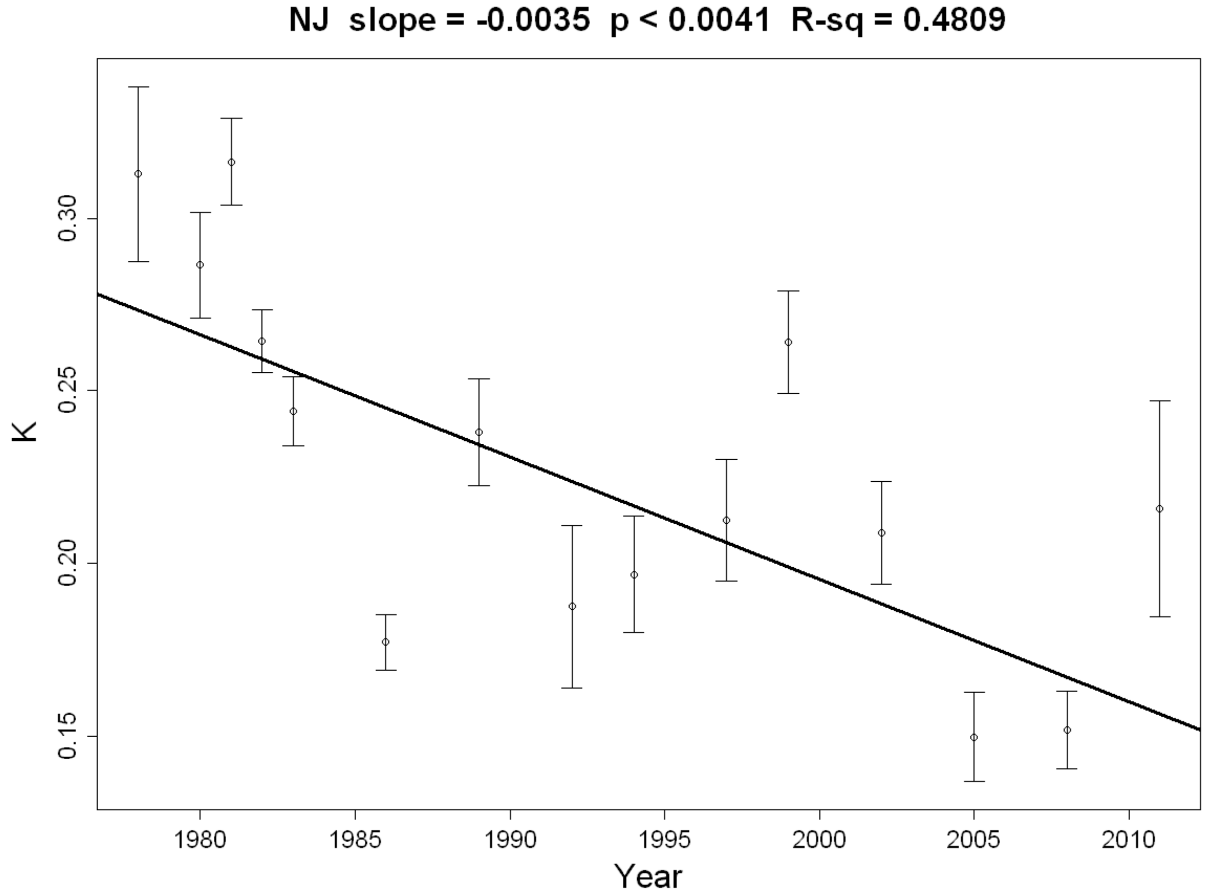


Figure A65. Weighted regression of *K* estimated in NJ over time.

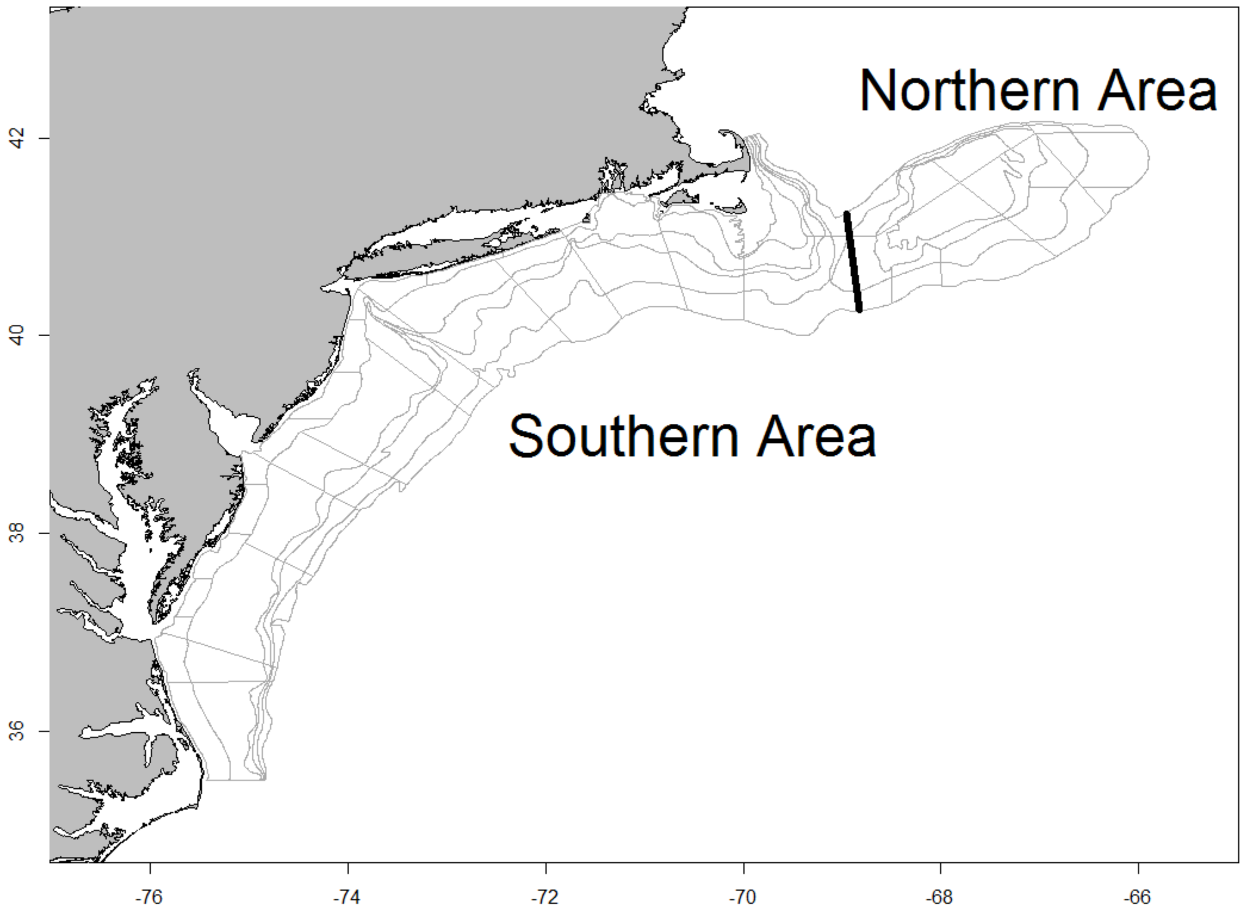


Figure A66. The proposed stock division. The northern area is GBK and the southern area is the remaining portion of the surfclam range in the US EEZ.

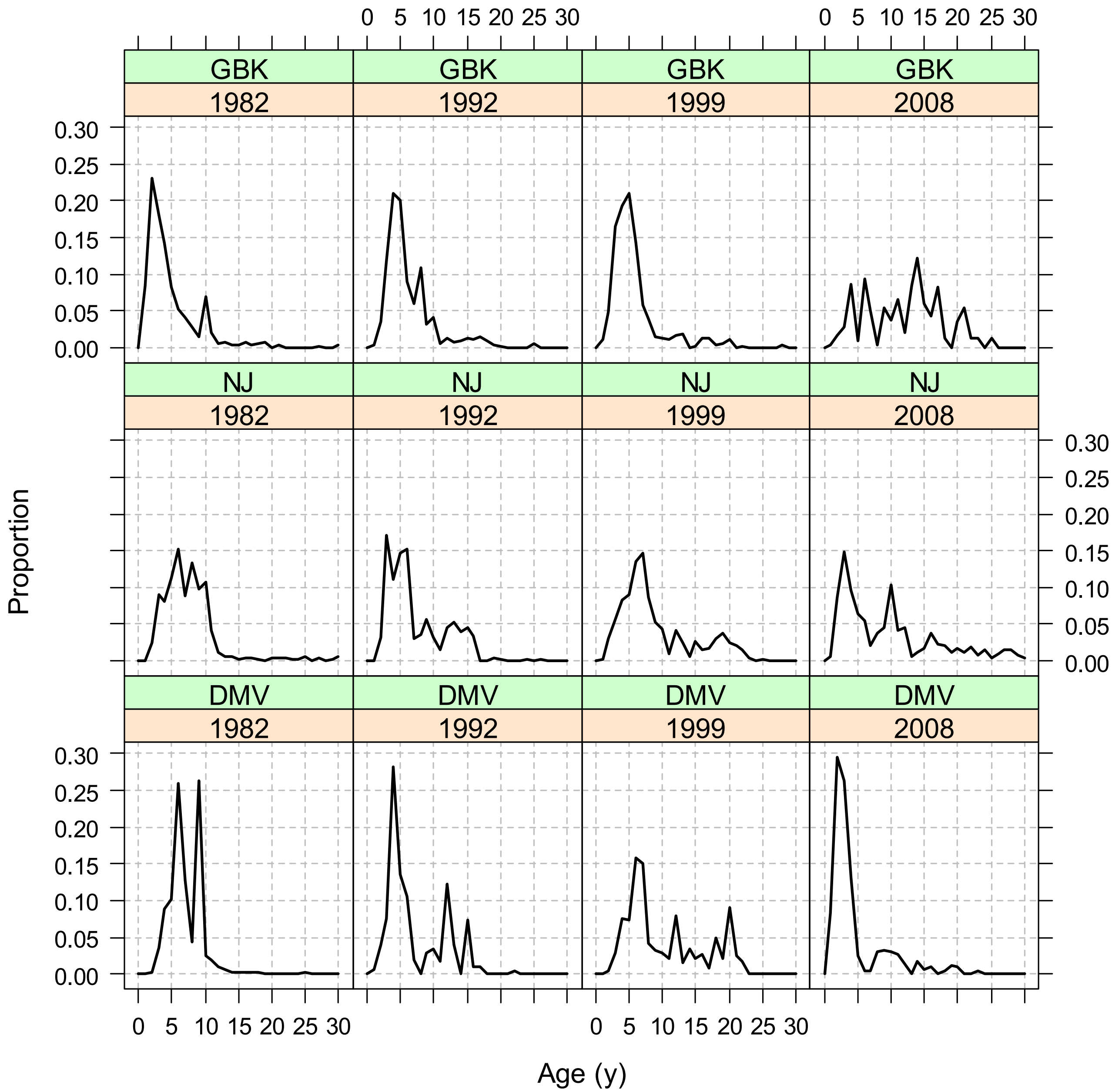


Figure A67. Survey age composition data for survey years and regions with at least 100 age samples. The first column, for example, shows the age composition of survey data for Georges Bank (GBK) in the north and New Jersey (NJ) and Delmarva (DMV) in the south during 1982.

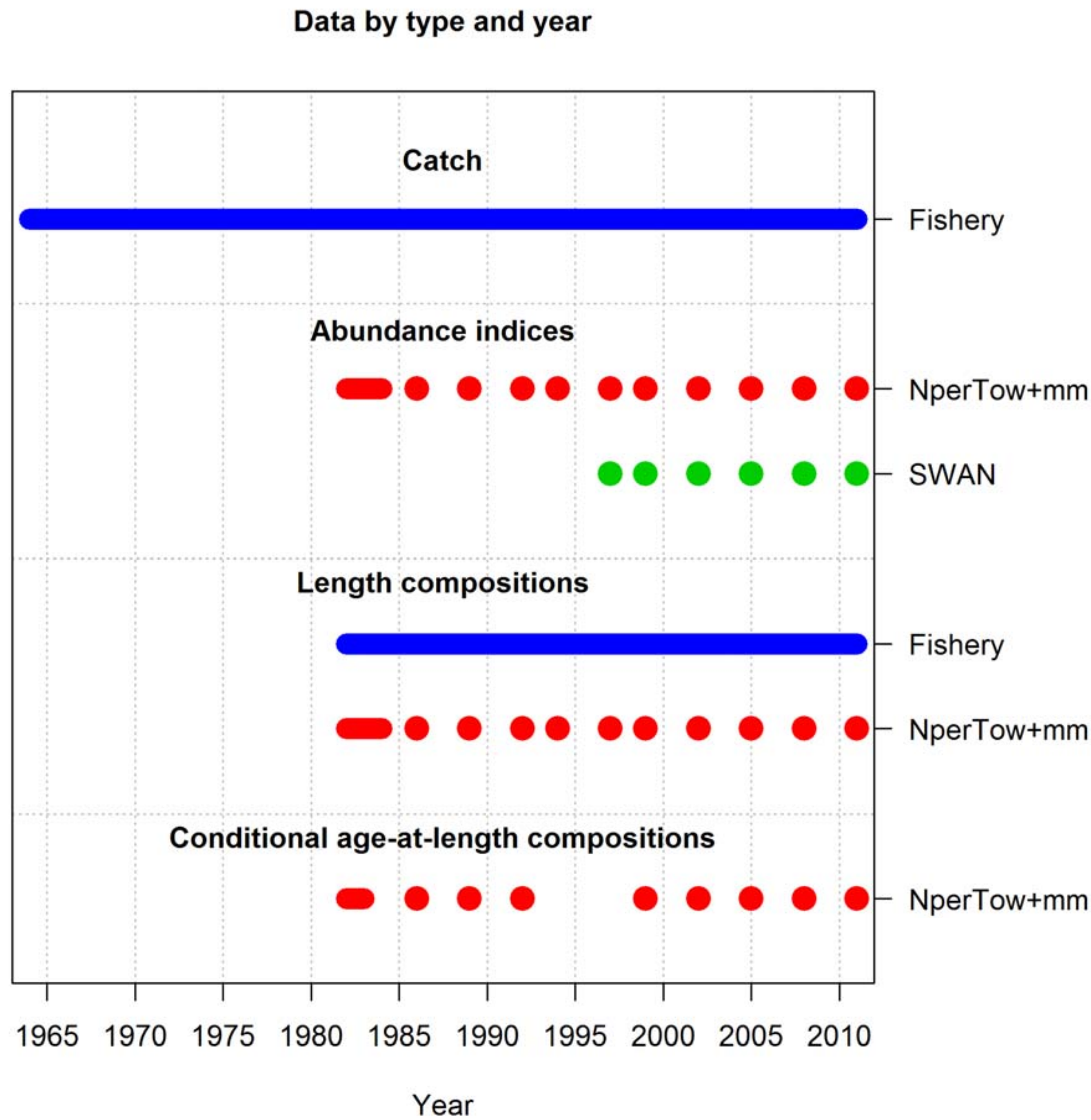


Figure A68. Data and availability by year in the SS3 model for surfclams in the southern area.

igure A69. Data and availability by year in the SS3 model for surfclams in the GBK area.

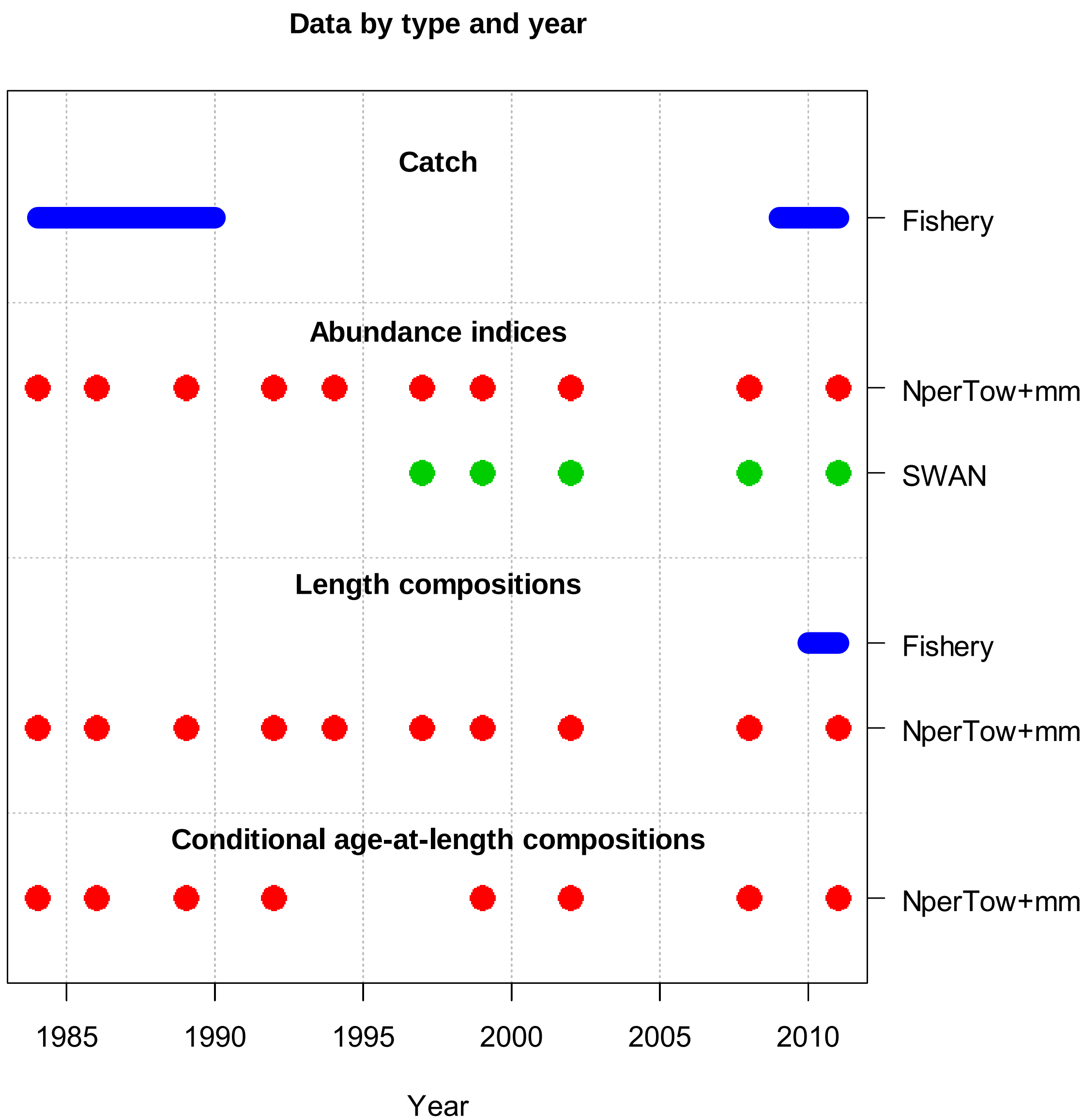


Figure A69. Data and availability by year in the SS3 model for surfclams in the GBK area.

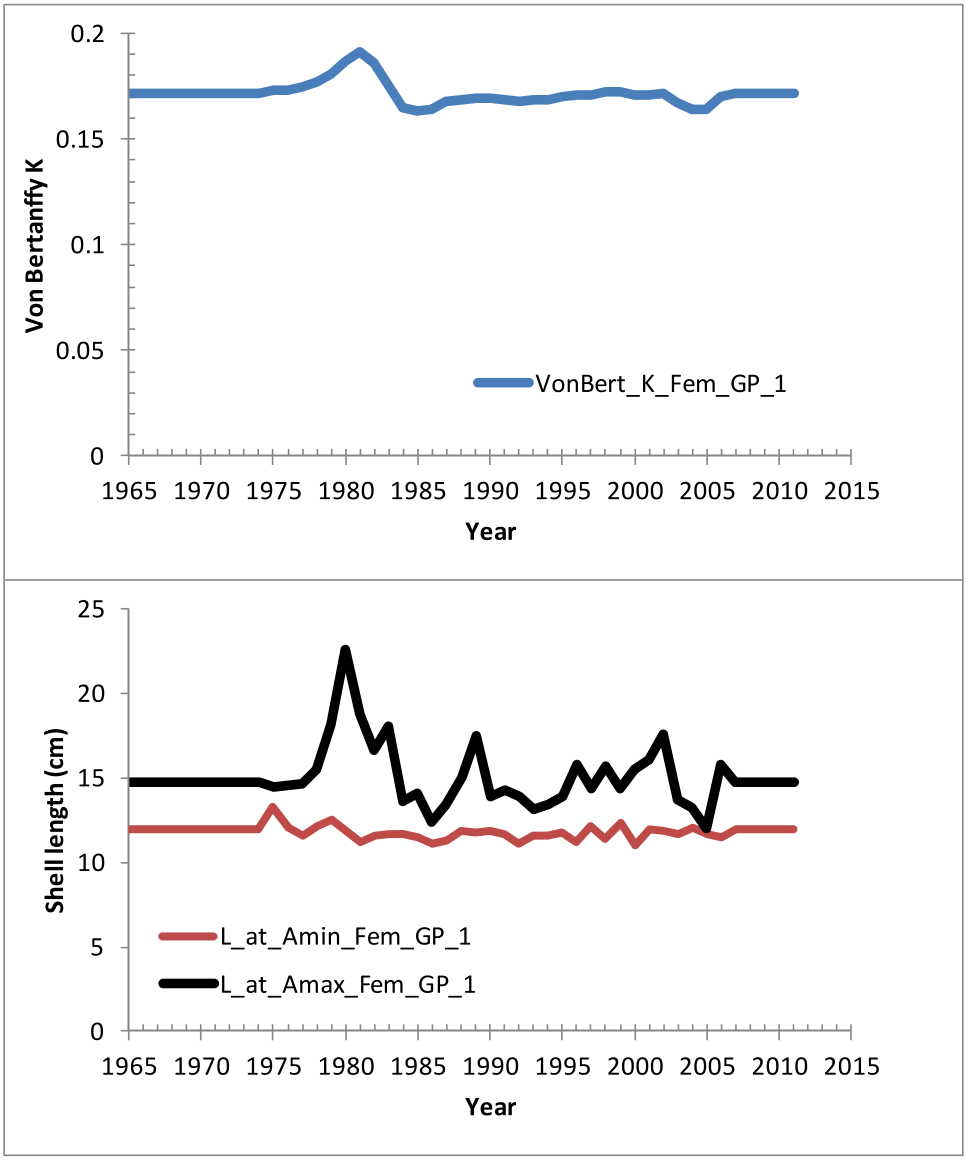


Figure A70. Results of sensitivity analyses in which growth parameters for surfclams in the southern area were estimated as random walks.

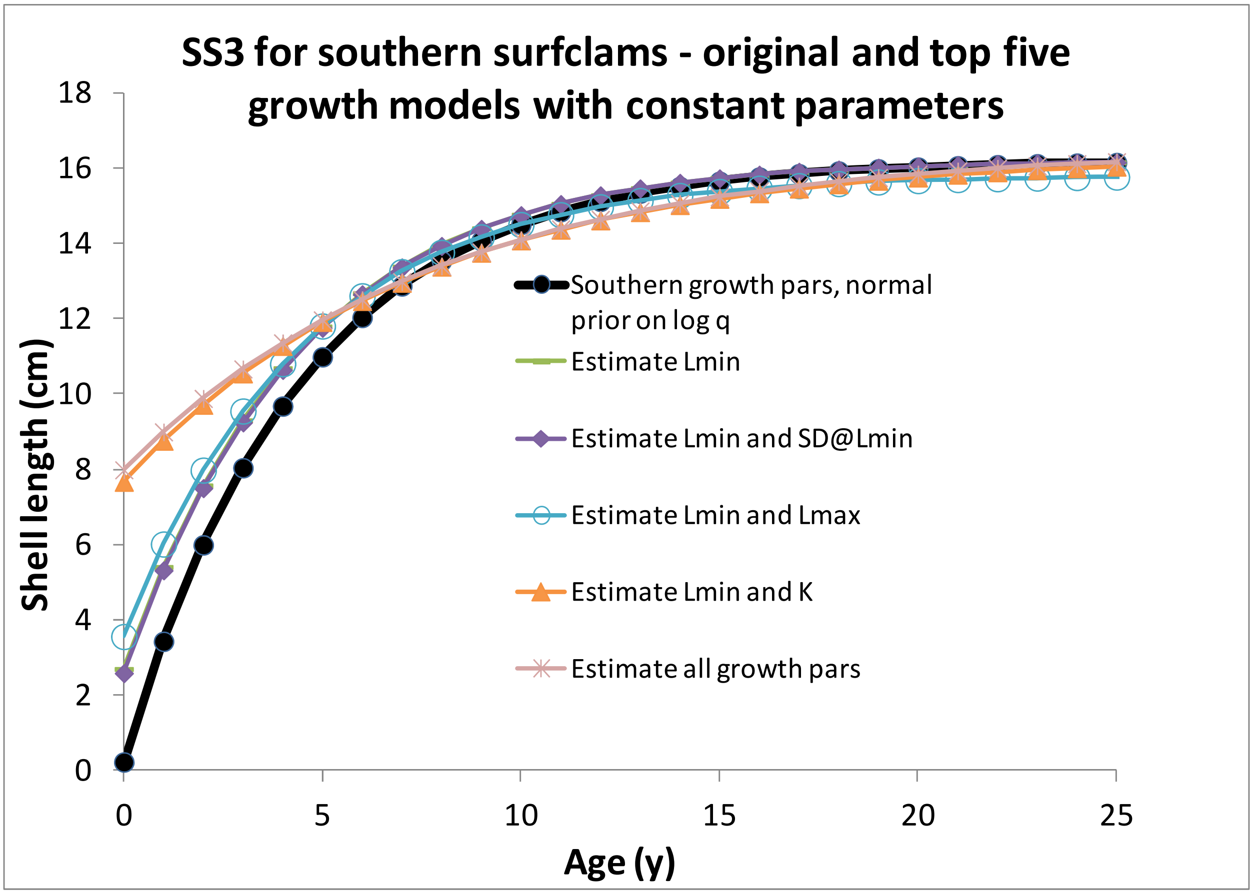


Figure A71. Growth curves estimated in preliminary SS3 model runs for surfclams in the south. The first curve listed in the legend is from external (initial) estimates of all growth parameter values that were fixed in SS3. The rest of the curves listed in the legend from top to bottom gave the best fit (lowest NLL) for the entire model and are listed in order of improving goodness of fit (decreasing NLL). The preferred growth model configuration was "Estimate Lmin and Lmax" (light blue line with open circle). In SS3, with Amin=4, growth at ages 0-4 is approximated by a linear term through zero so that the important of differences on the far left hand side are minimized.

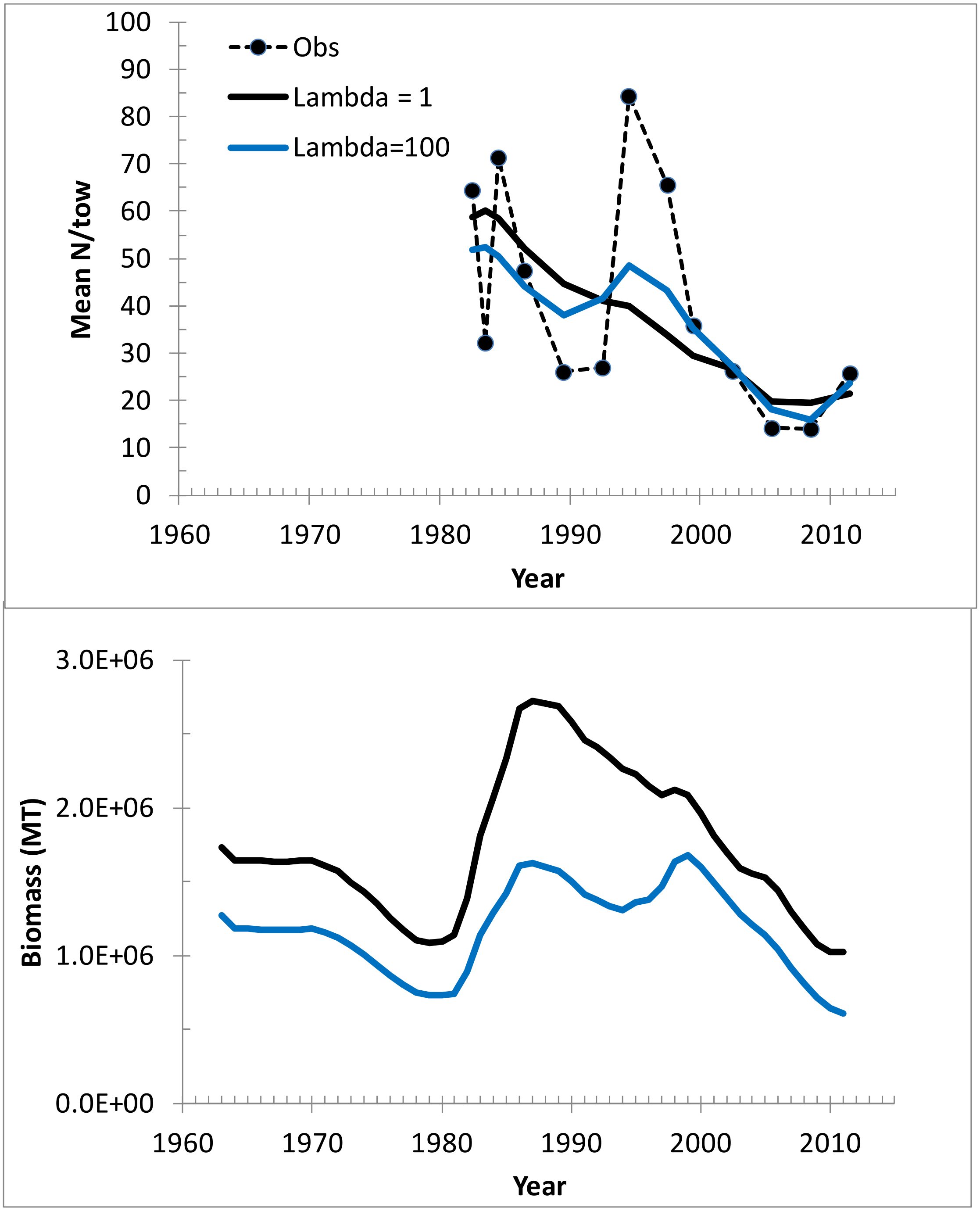


Figure A72. Observed survey data, predicted survey values and biomass estimates from two preliminary SS3 models with likelihood weights for survey trends lambda=1 and lambda=100.

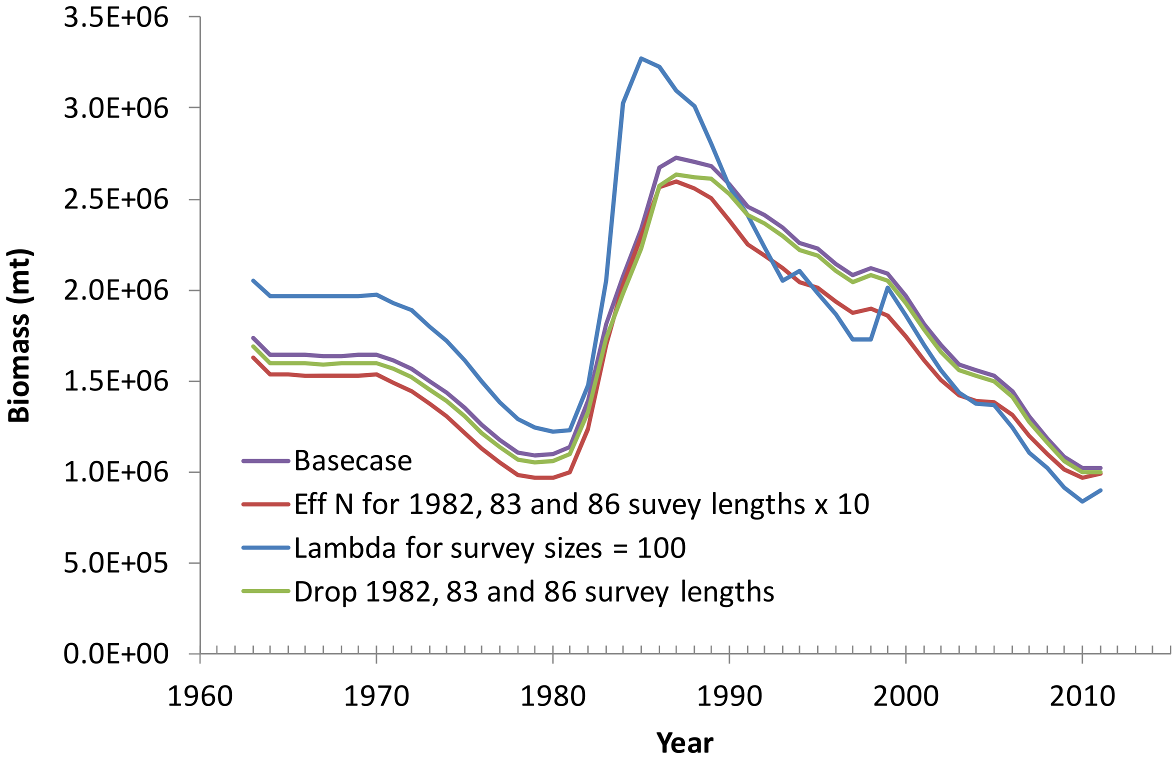


Figure A73. Biomass estimates from sensitivity analyses using a preliminary SS3 model for surfclams in the southern area to address lack of fit to survey size data for 1982, 1983 and 1986.

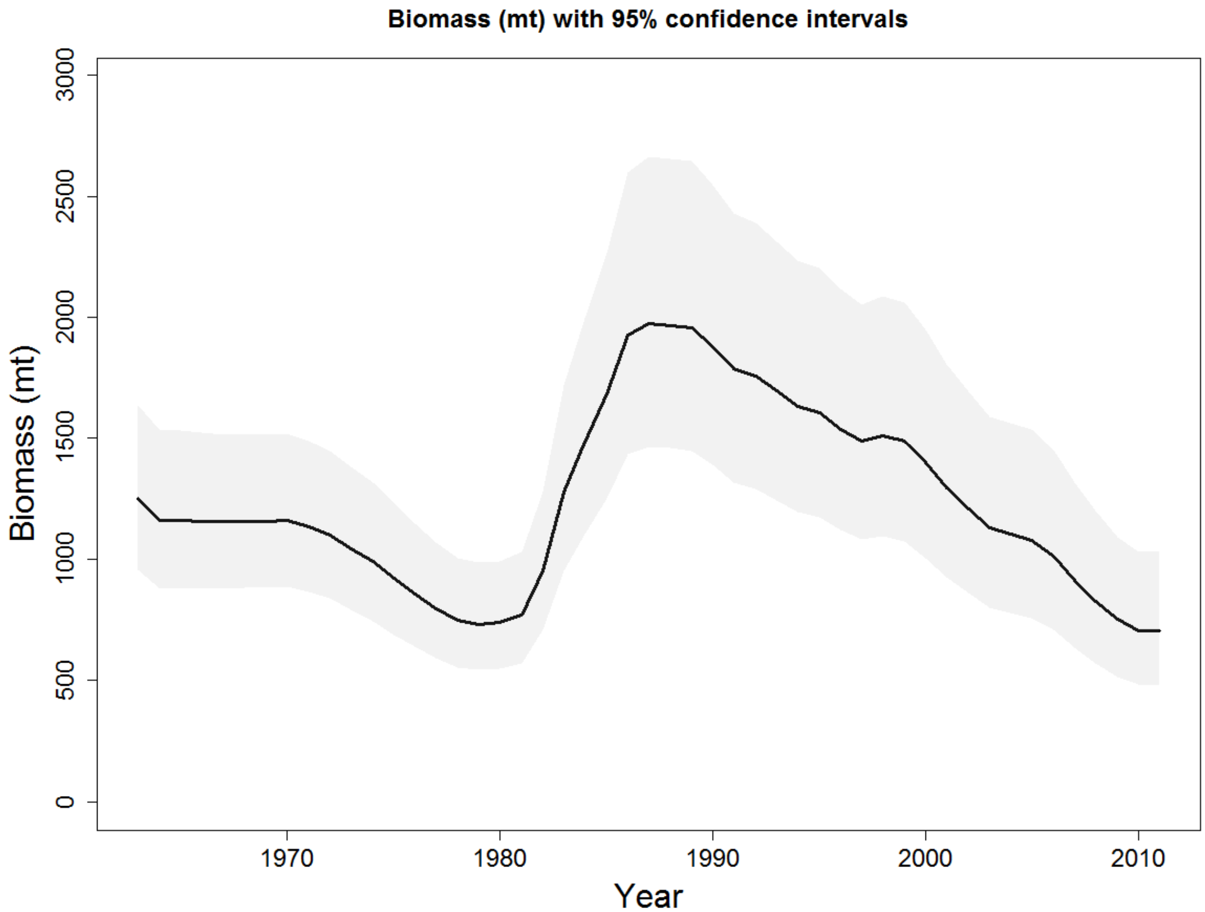


Figure A74. Biomass estimates for surfclams in the southern area from SS3, with 95% confidence intervals.

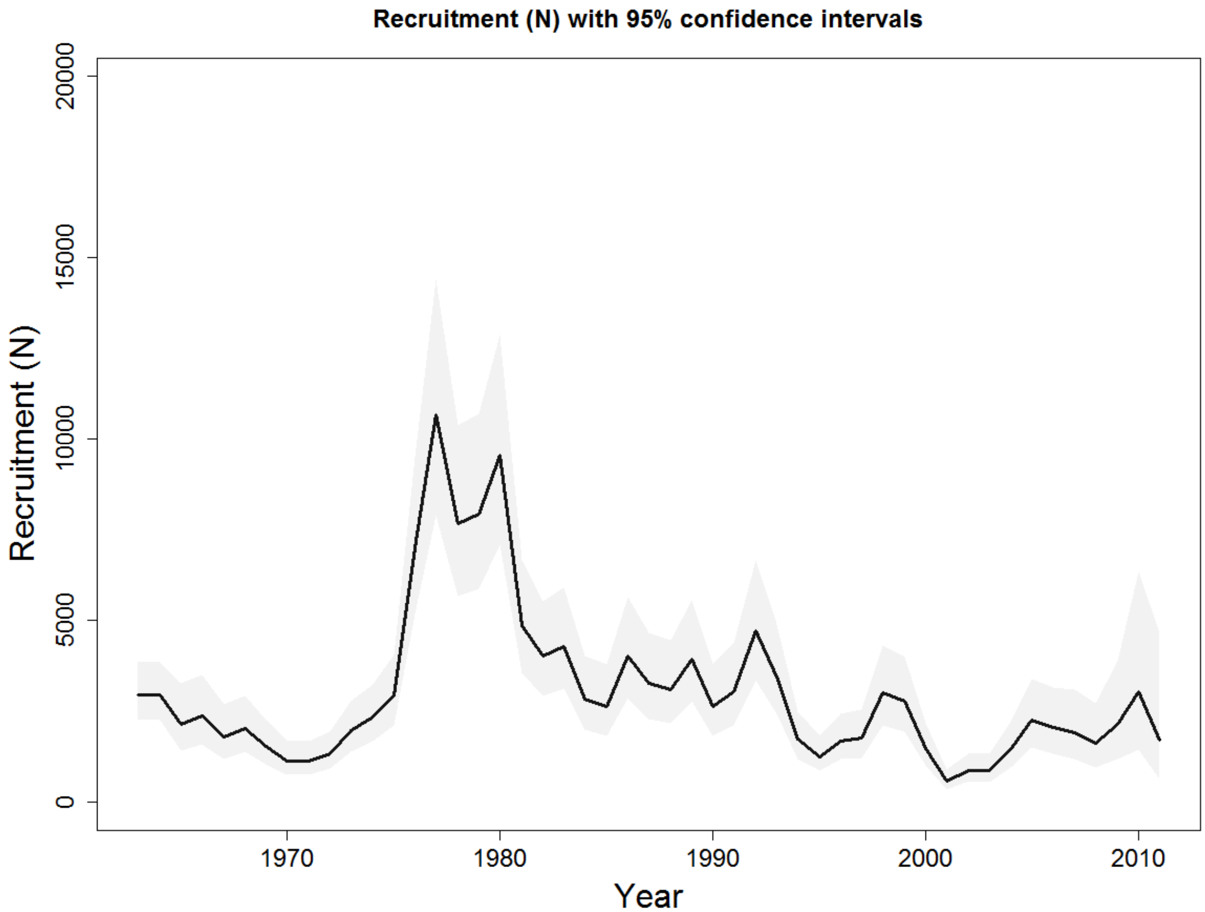


Figure A75. Recruitment estimates (thousands, age 0) for surfclams in the southern area from SS3, with 95% confidence intervals.

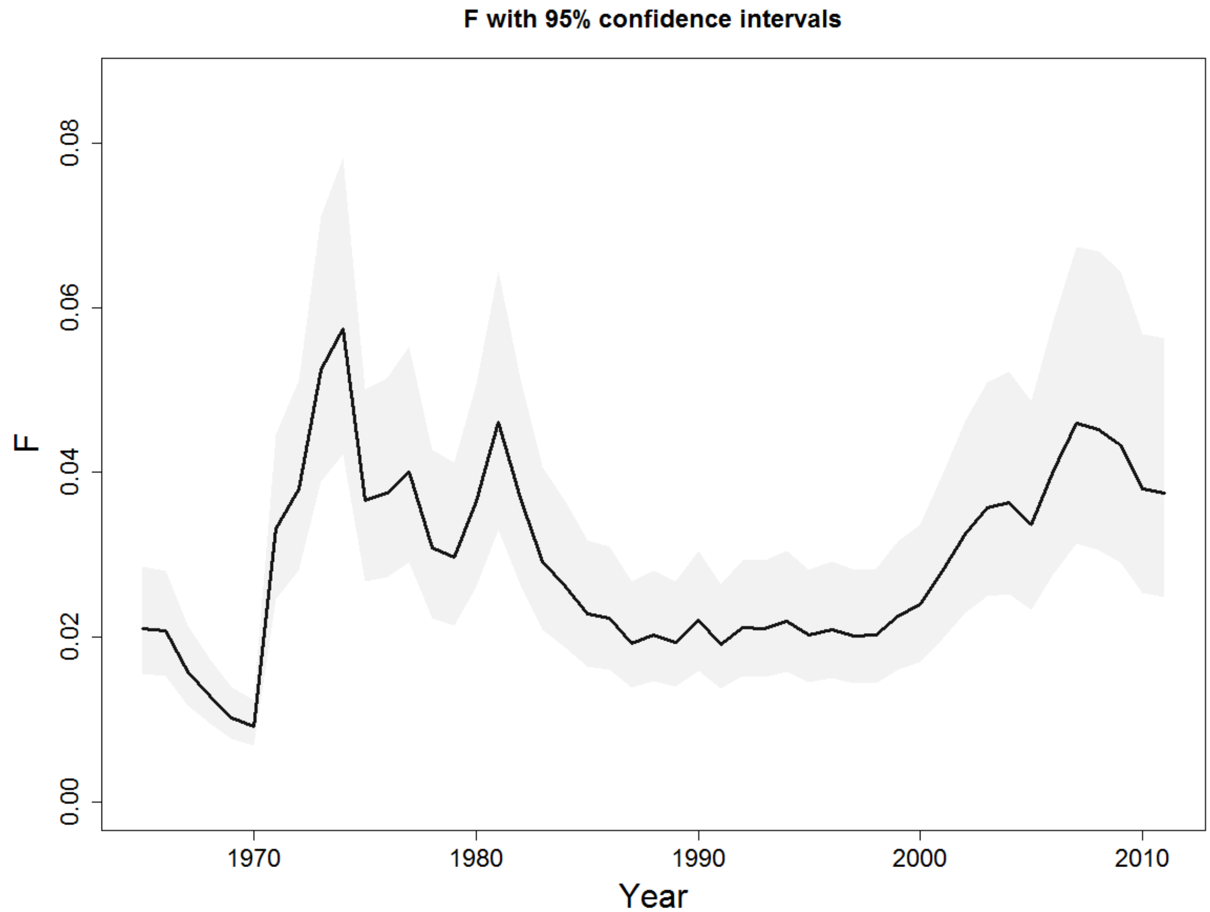


Figure A76. Fully recruited fishing mortality estimates for surfclams in the southern area from SS3, with 95% confidence intervals.

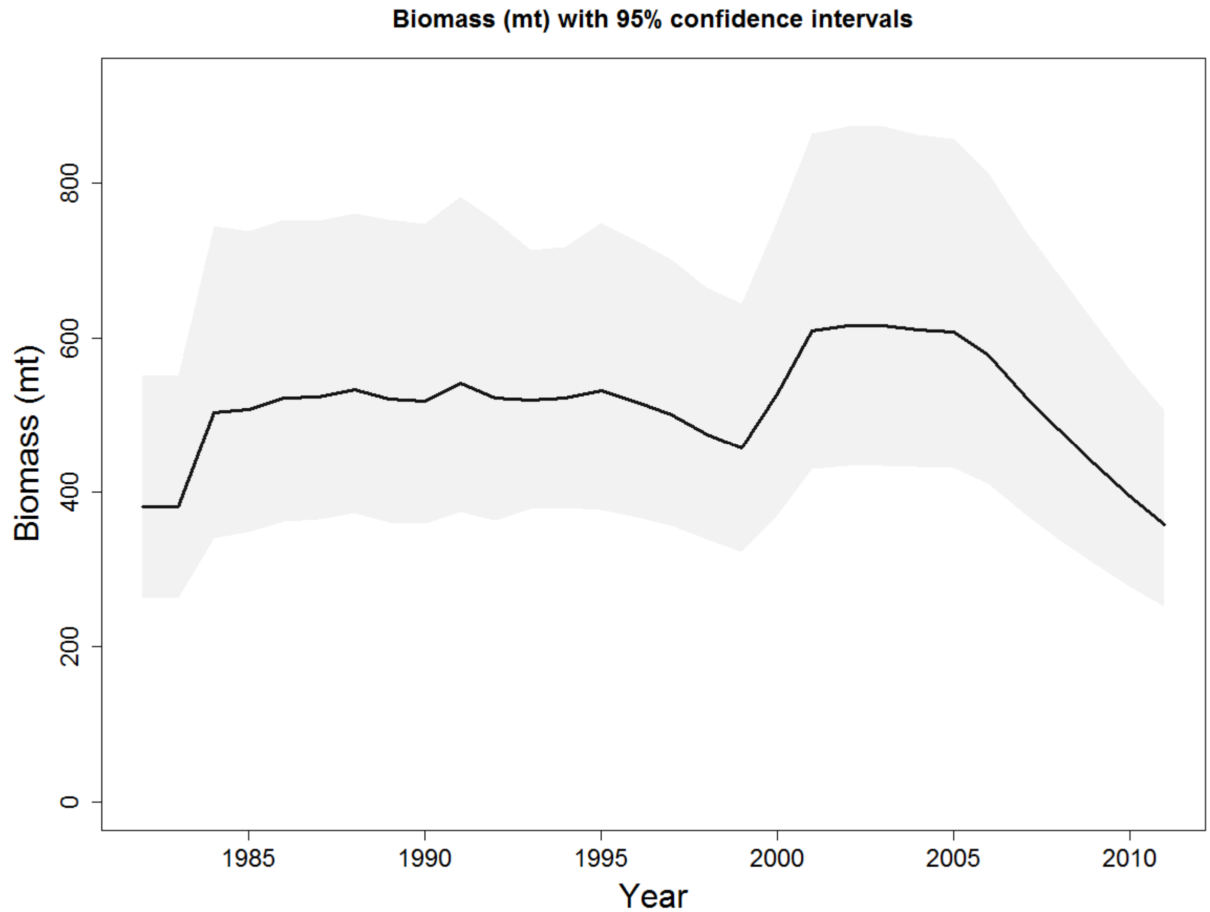


Figure A77. Biomass estimates for surfclams in the GBK area from SS3, with 95% confidence intervals.

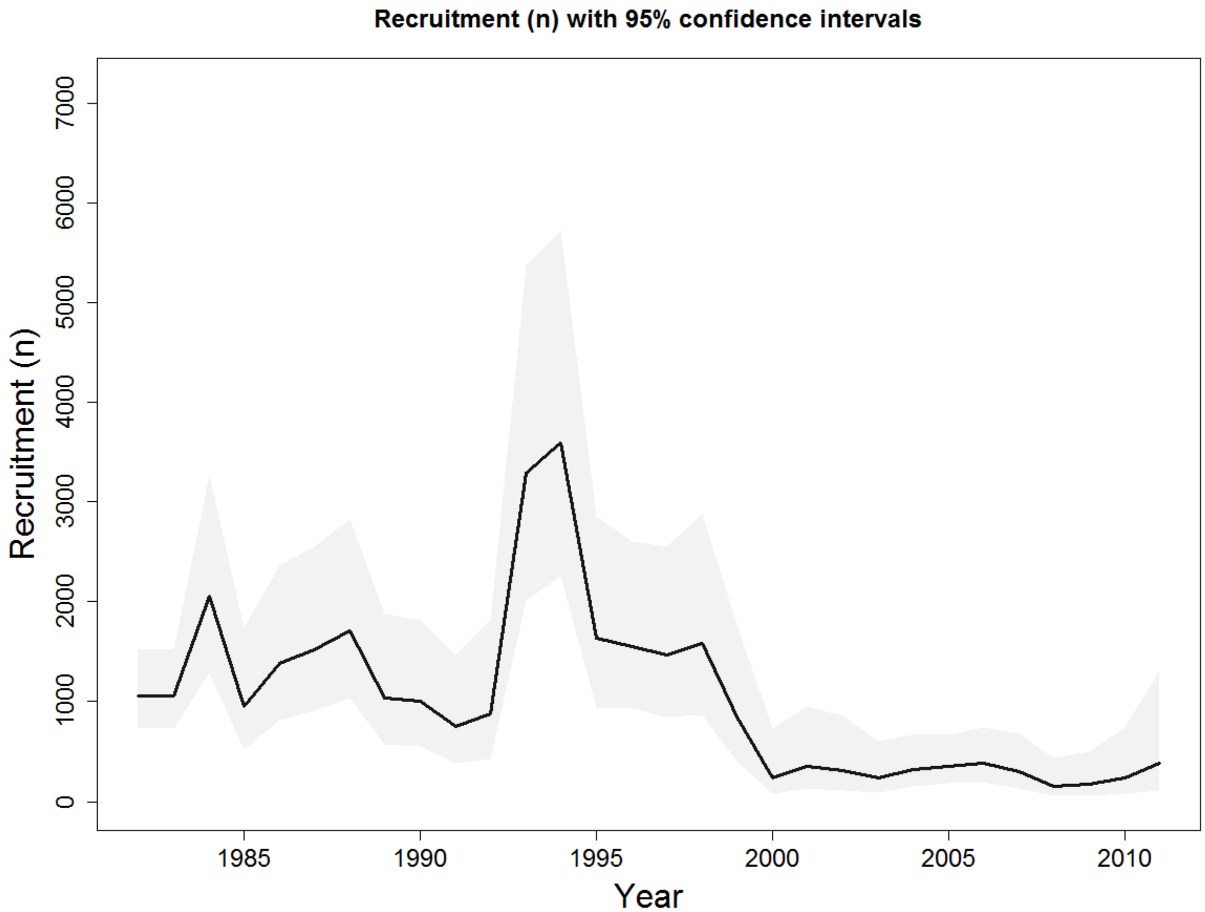


Figure A78. Recruitment estimates (thousands, age 0) from the northern area from SS3, with 95% asymptotic confidence intervals.

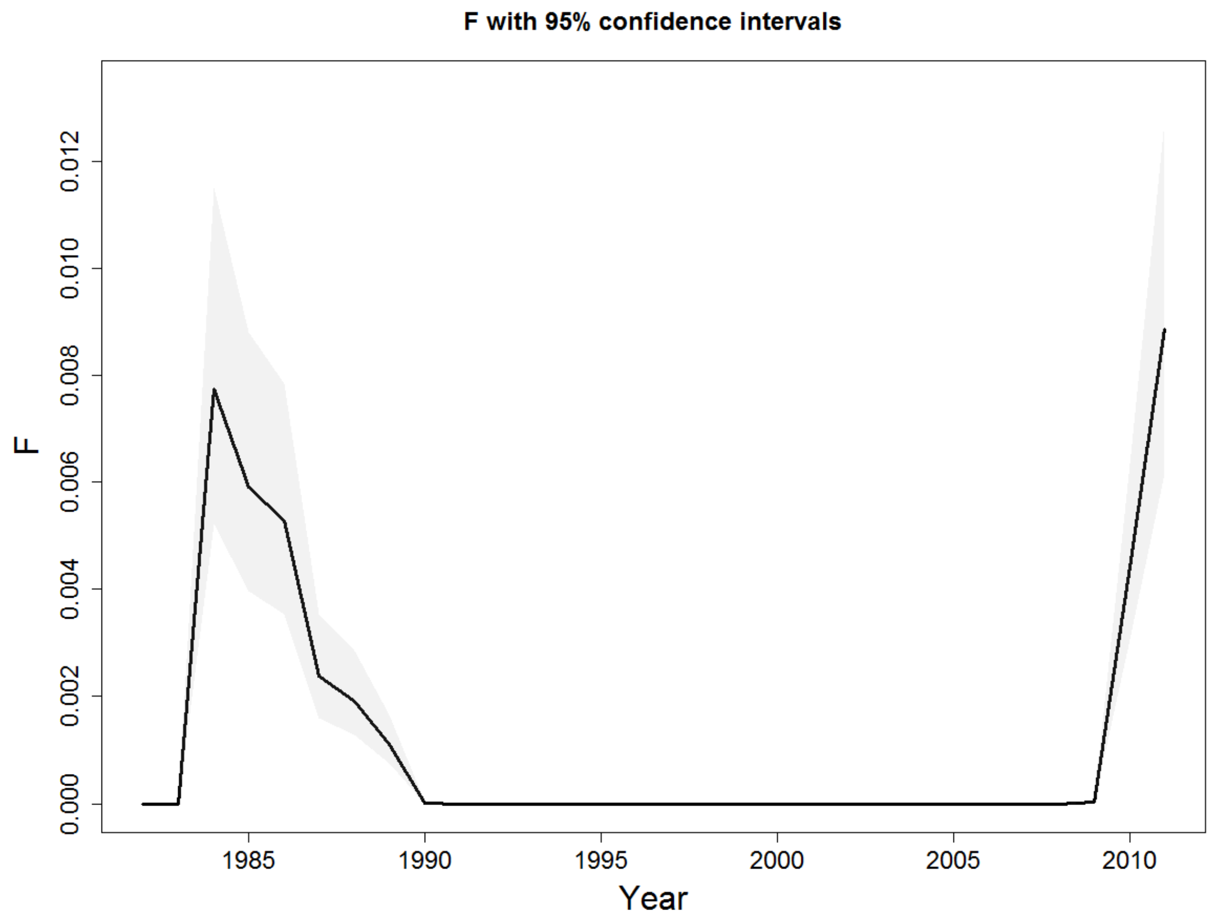


Figure A79. Fully recruited fishing mortality estimates from the GBK area, with 95% confidence intervals.

A)

B)

C)

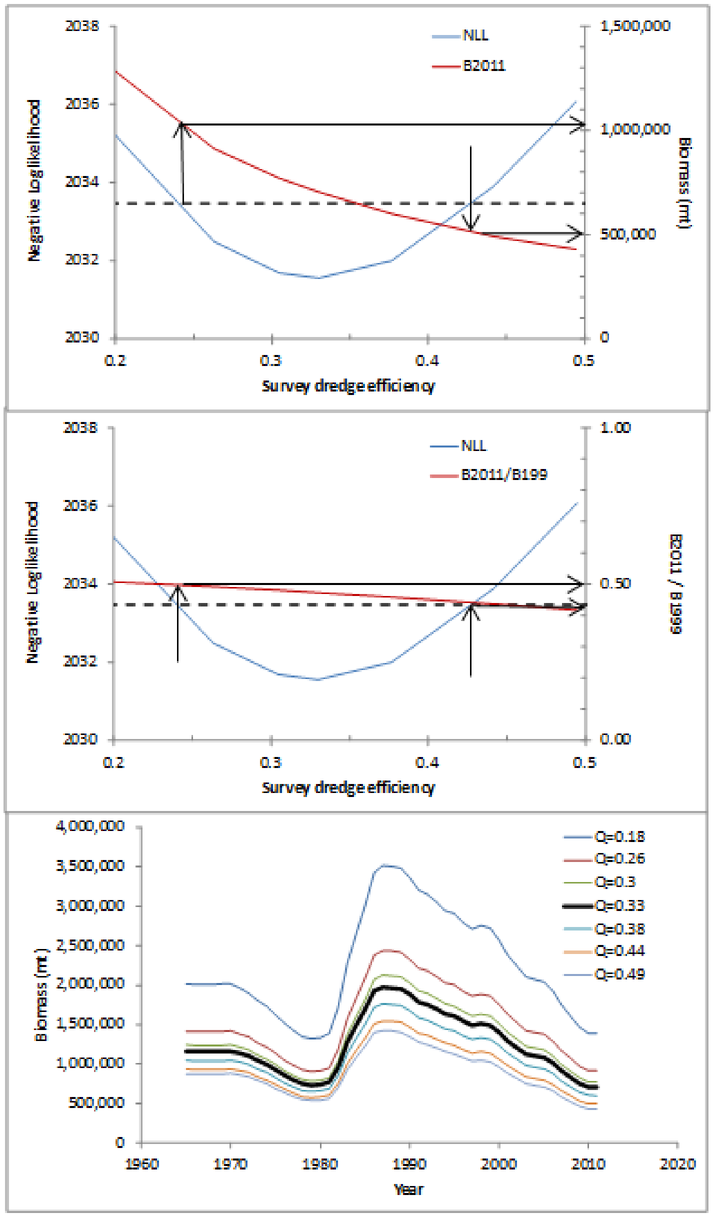


Figure A80. Likelihood profile analysis for survey dredge efficiency, 2011 biomass and the biomass status ratio (B_{2011}/B_{1999}) using the basecase SS3 model for surfclams in the southern area. The dashed line in panels A) and B) can be used to find bounds for approximate 95% confidence intervals. In particular, if two vertical lines are drawn through the intersection of the dashed black and blue likelihood lines, then the confidence interval bounds for dredge efficiency are found where the vertical lines intersect the x-axis and where the vertical lines intersect the red lines for biomass (A) and status ratio (B). Panel C) shows the effect on estimated biomass trend of fixing survey dredge efficiency at values between Q=0.18 and 0.49.

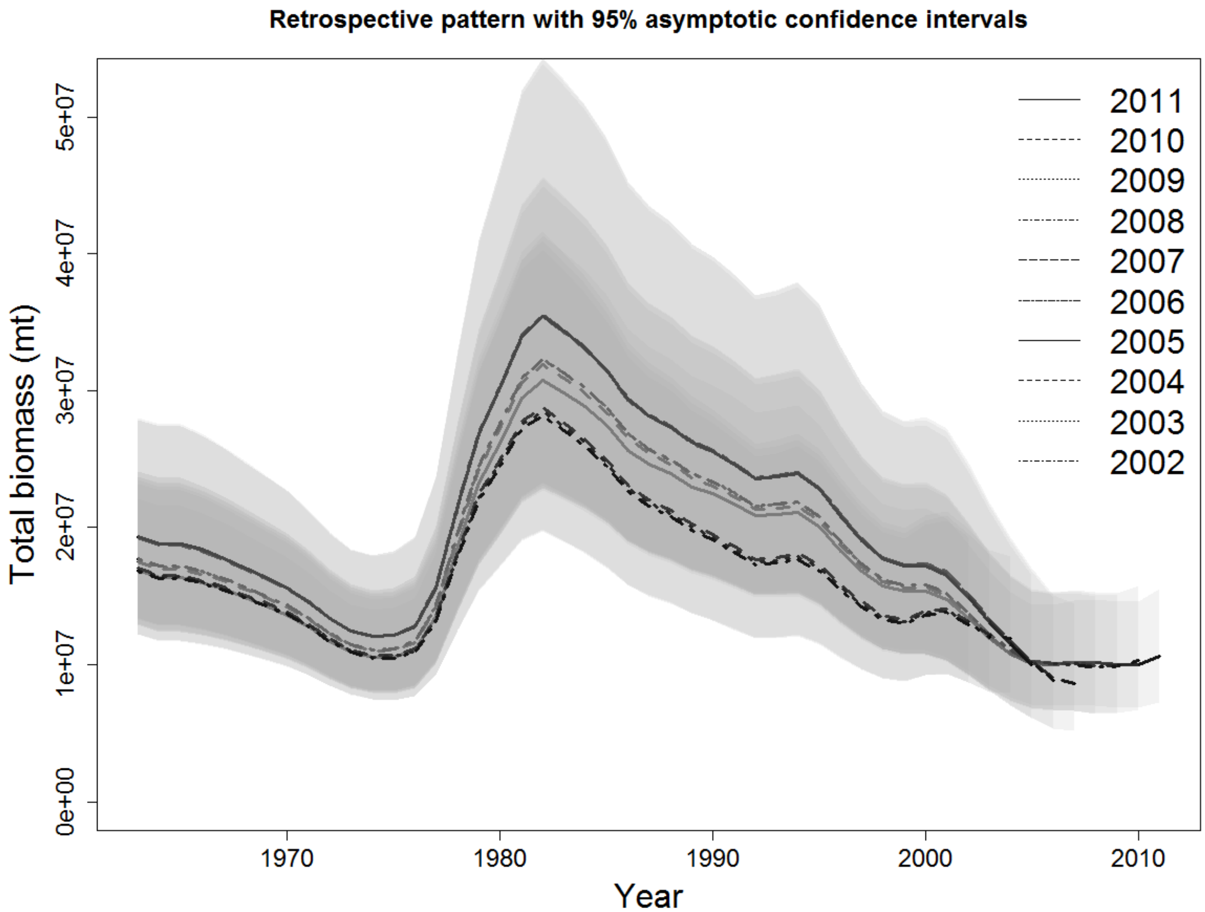


Figure A81. Internal retrospective pattern for biomass (ages 6+ y) from the southern area SS3 model. Mohn's $\rho = 0.02$ (9 year peel).

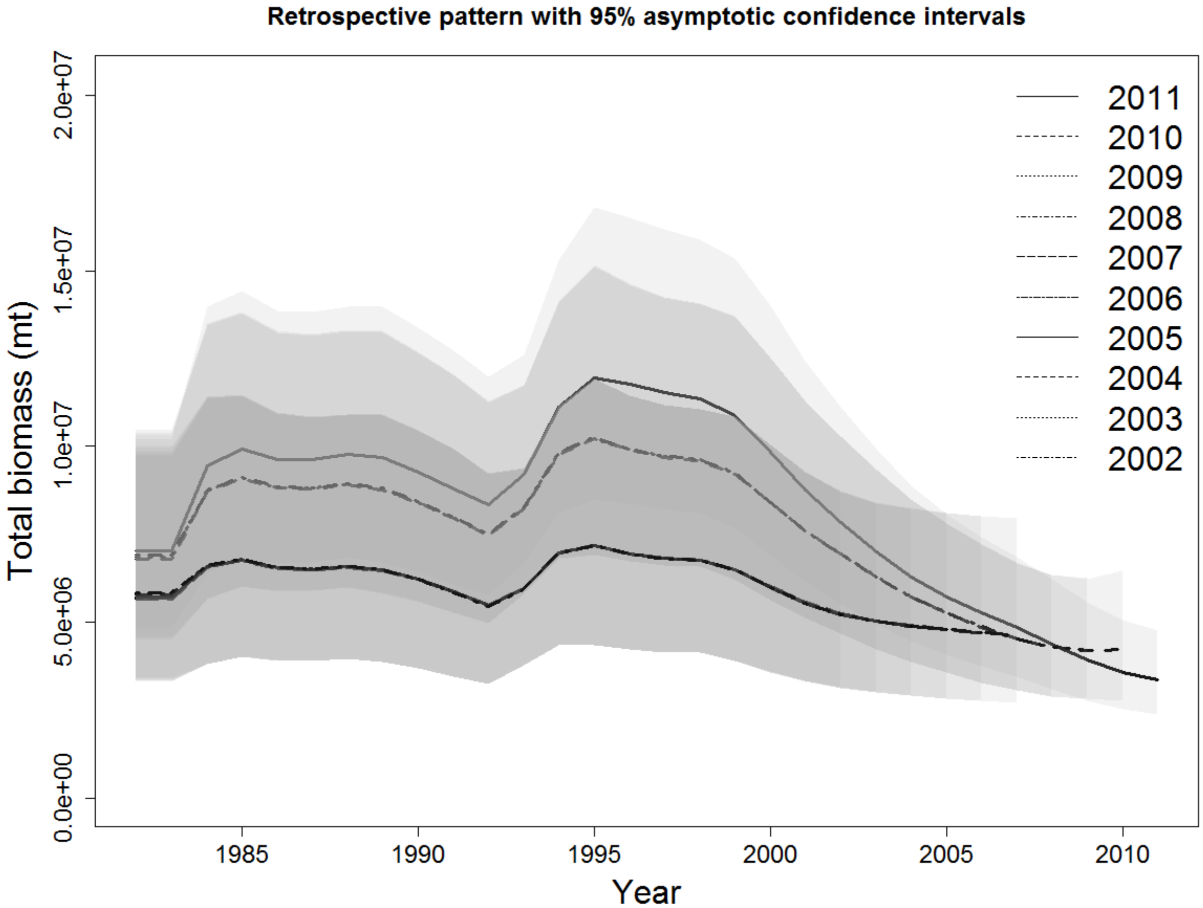


Figure A82. Internal retrospective pattern based on total biomass (ages 7+ y) from the GBK SS3 model. Mohn's ρ = 0.30 (9 year peel).

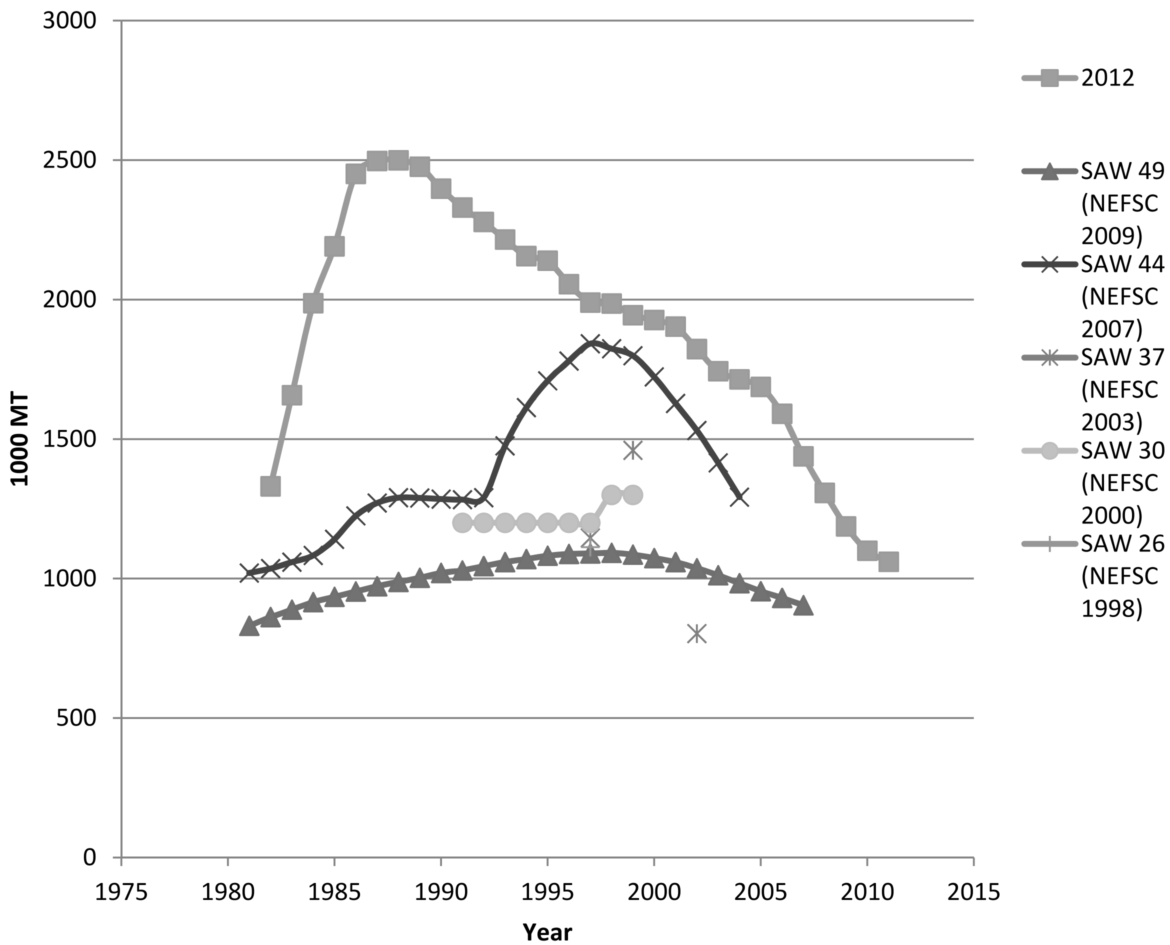


Figure A83. Historical retrospective comparing the biomass estimates for surfclams in the southern + GBK area from previous surfclam assessments.

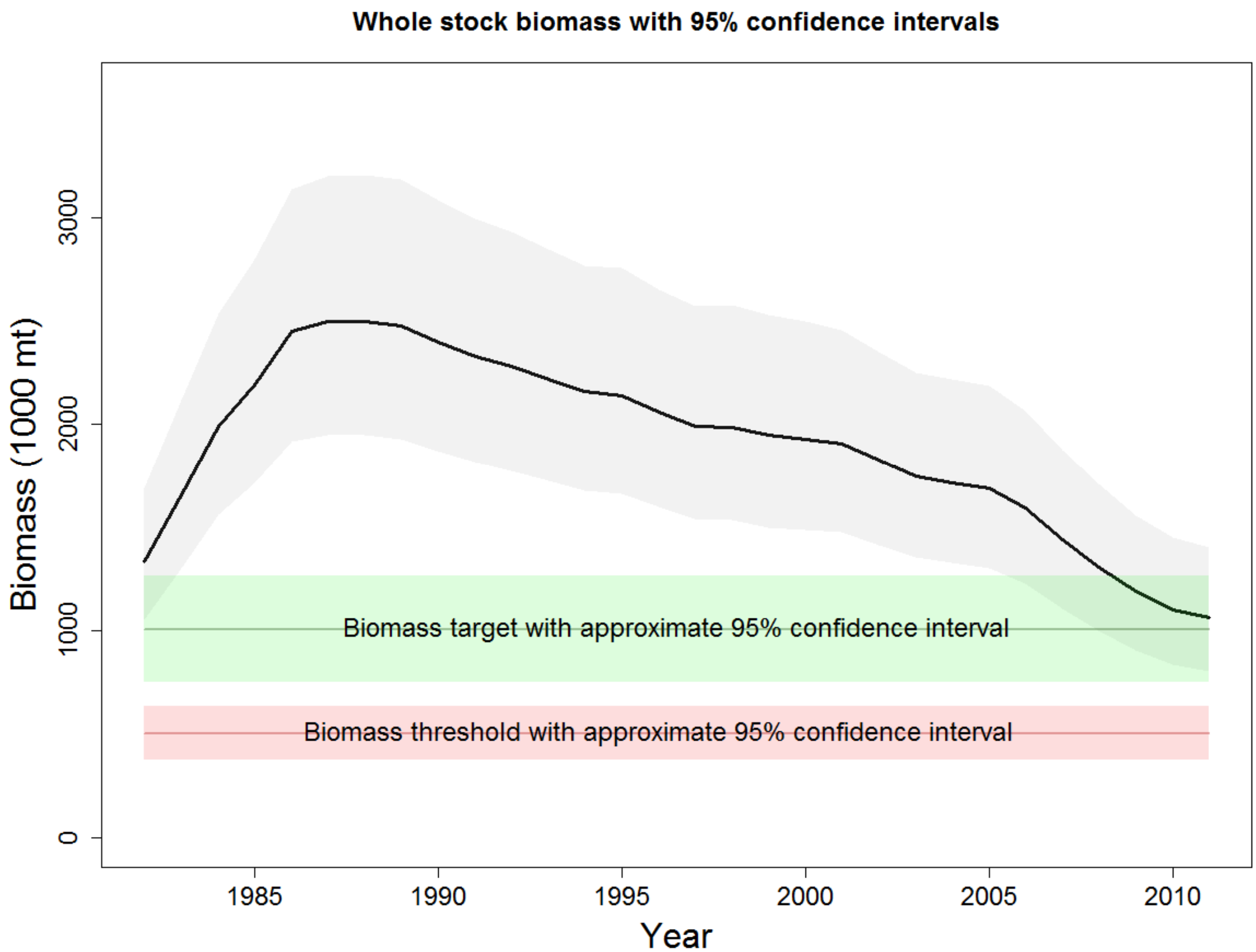


Figure A84. Whole stock biomass status estimates with cv and approximate 95% confidence intervals.

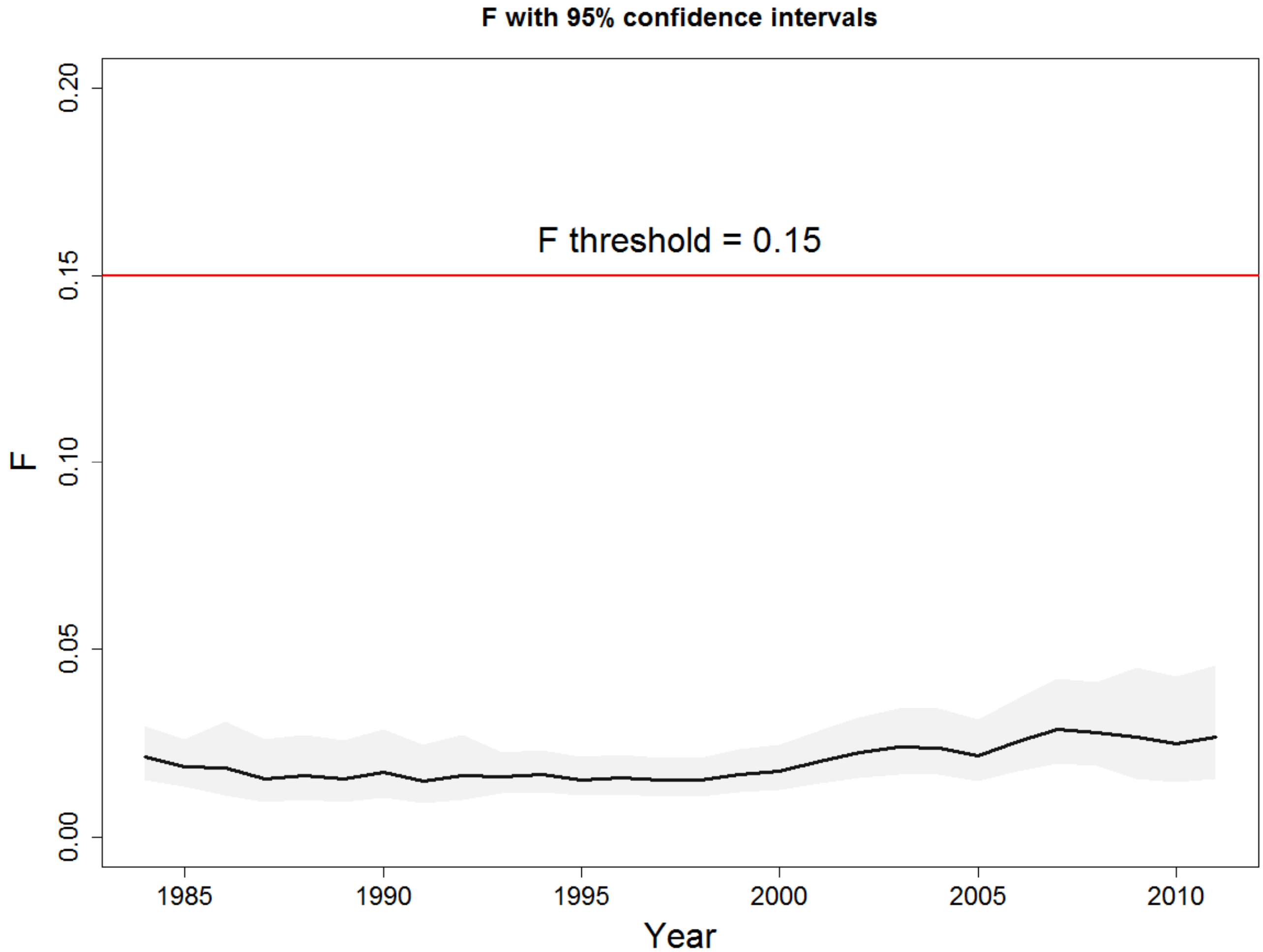


Figure A85. Whole stock F status estimates with cv and approximate 95% confidence intervals.

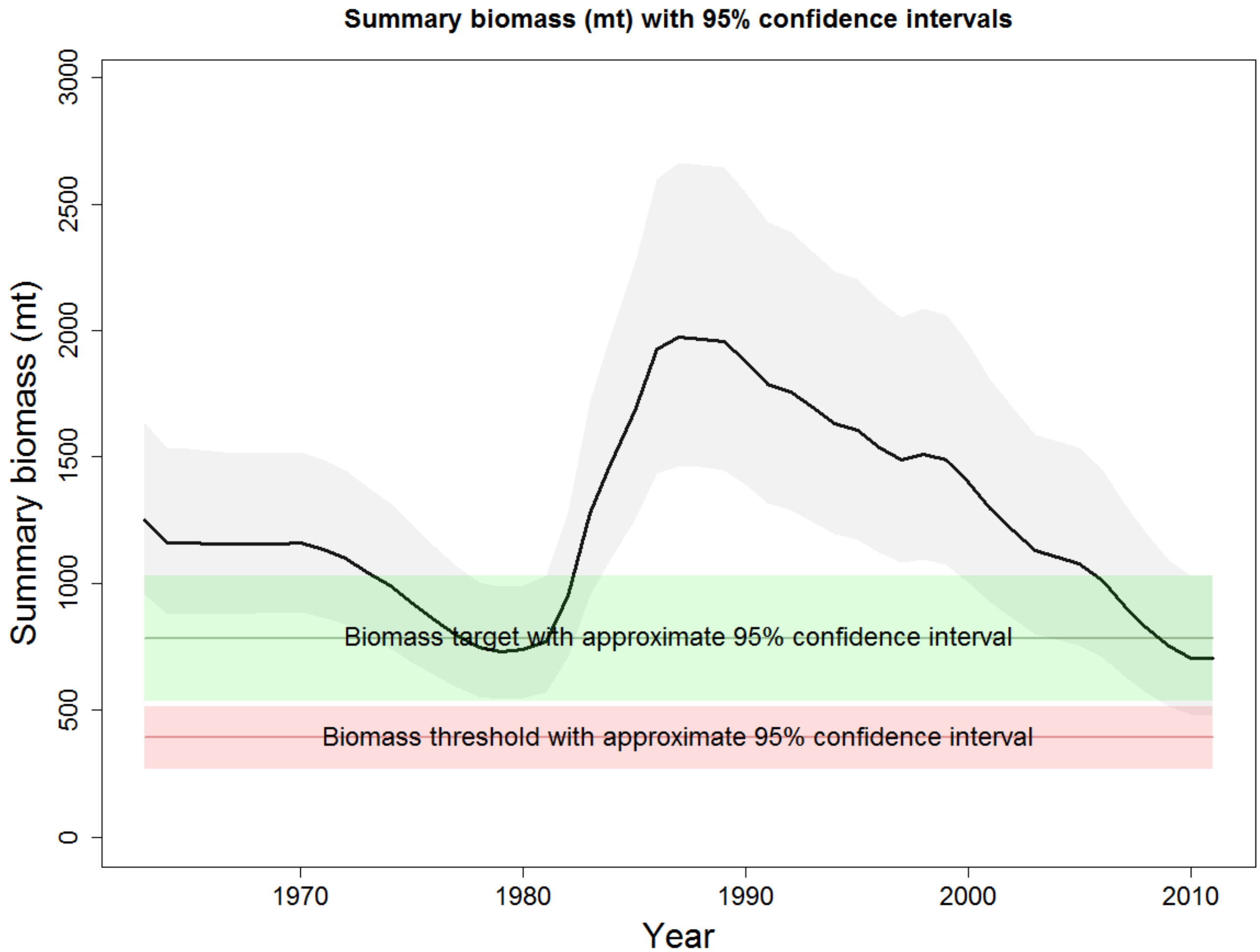


Figure A86. Southern area biomass status estimates with cv and approximate 95% confidence intervals.

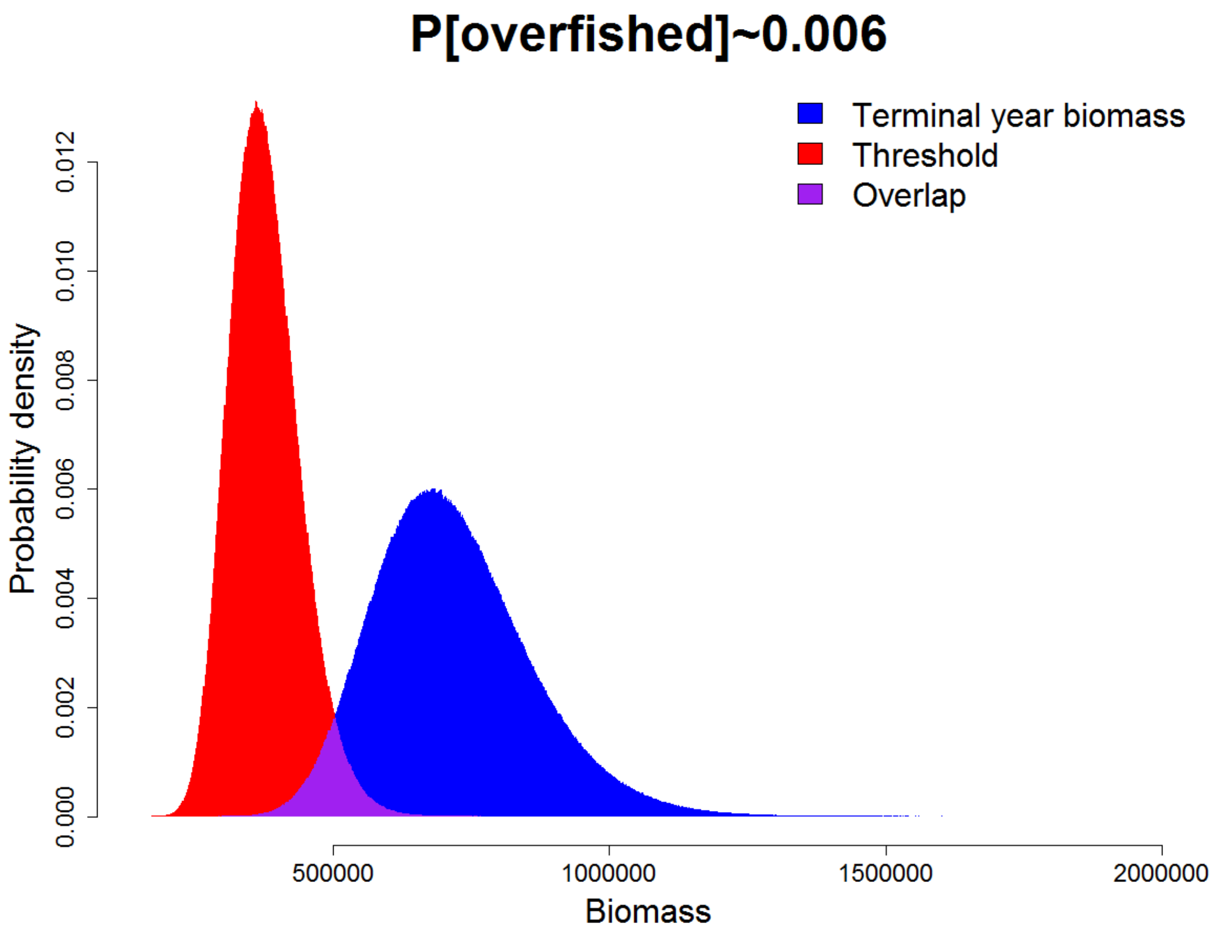


Figure A87. The distributions for B_{2011}~LogN(6.55,0.194) and $B_{THRESHOLD}$~LogN(5.92,0.167). The probability of being overfished is based on the methods of Shertzer et al. (2008).

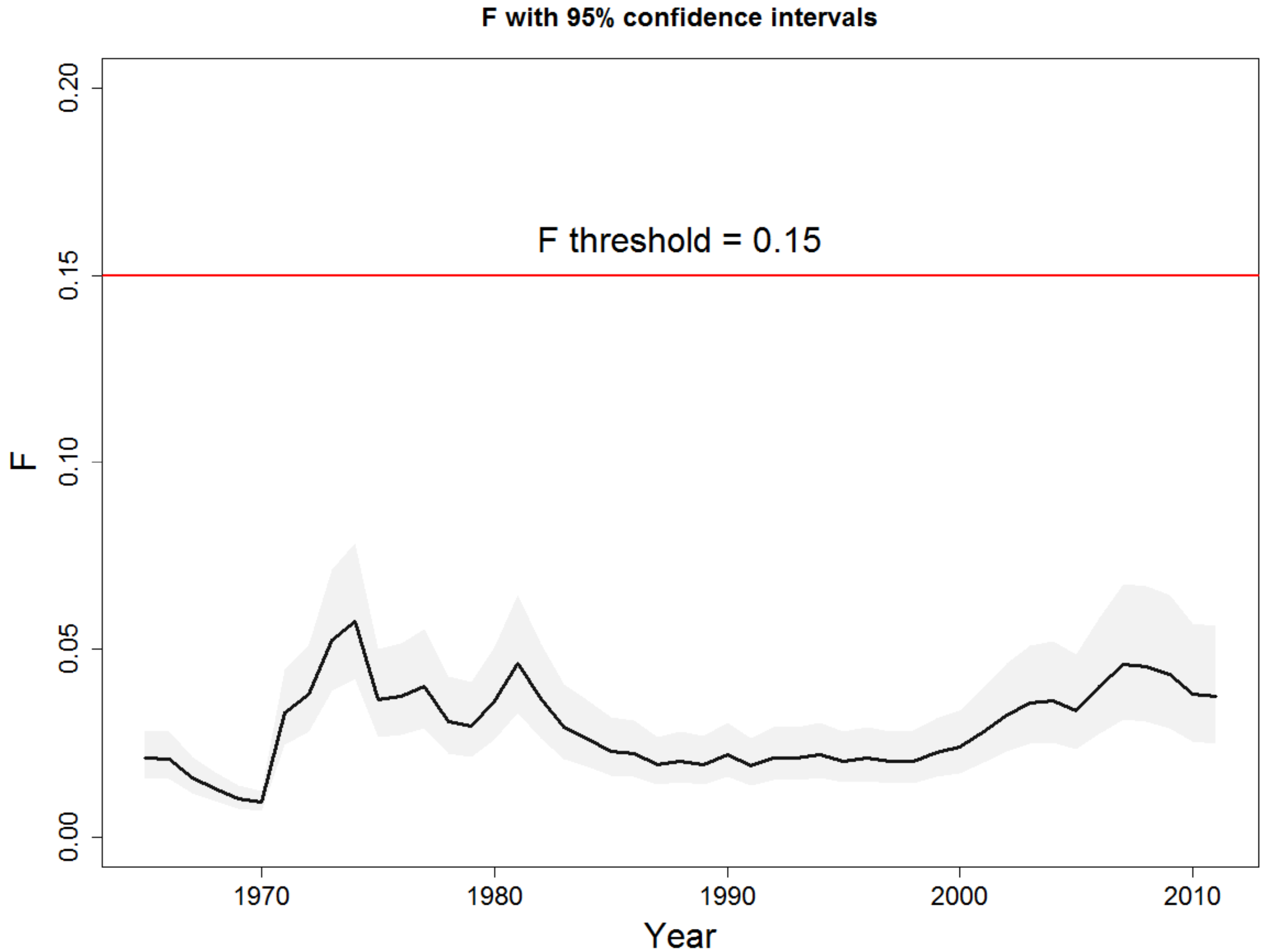


Figure A88. Southern area F status estimates with cv and approximate 95% confidence intervals.

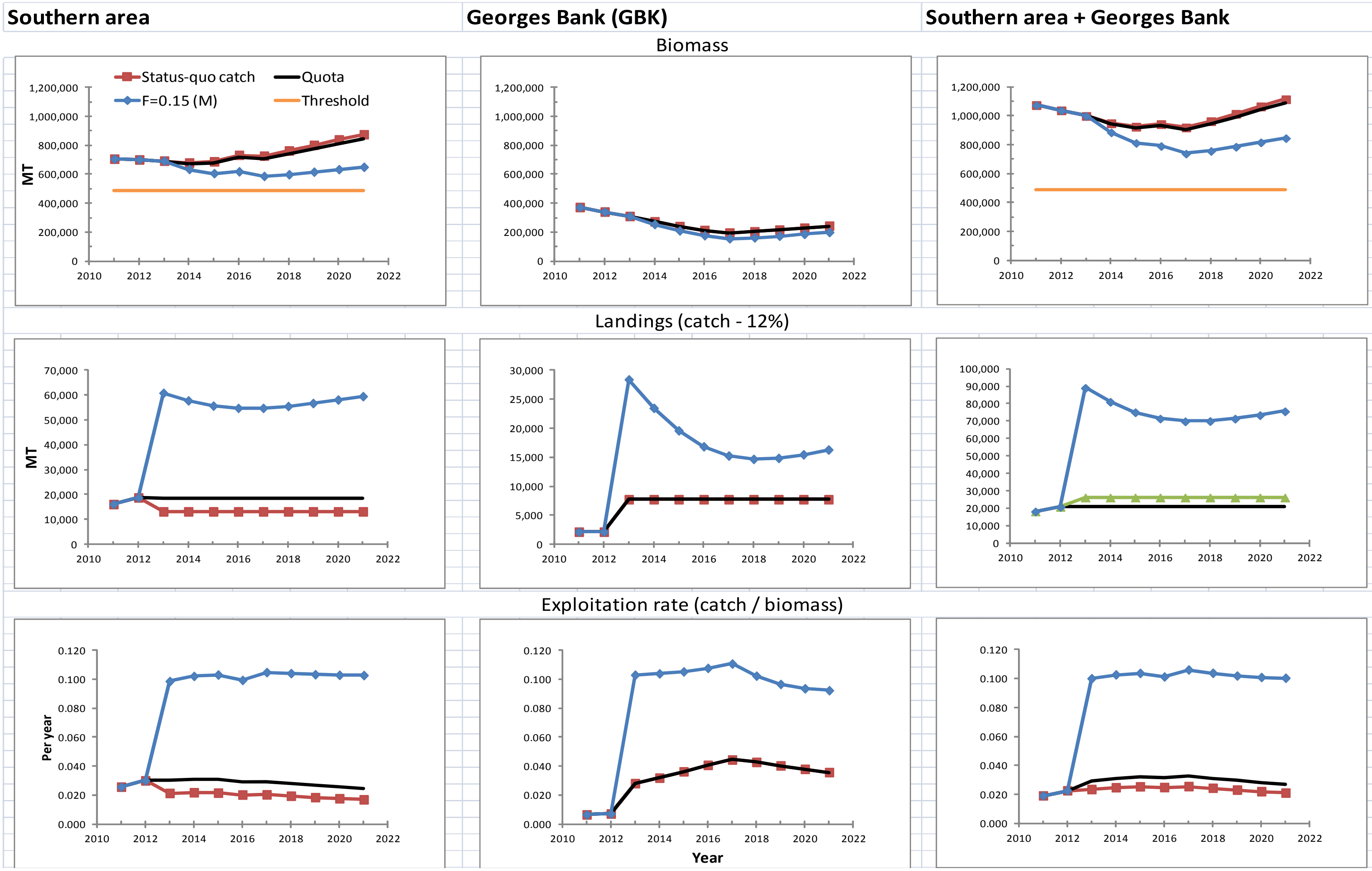


Figure A89. Projected biomass, landings and exploitation rates during 2012-2021 for surfclams in the southern, GBK and combined areas.

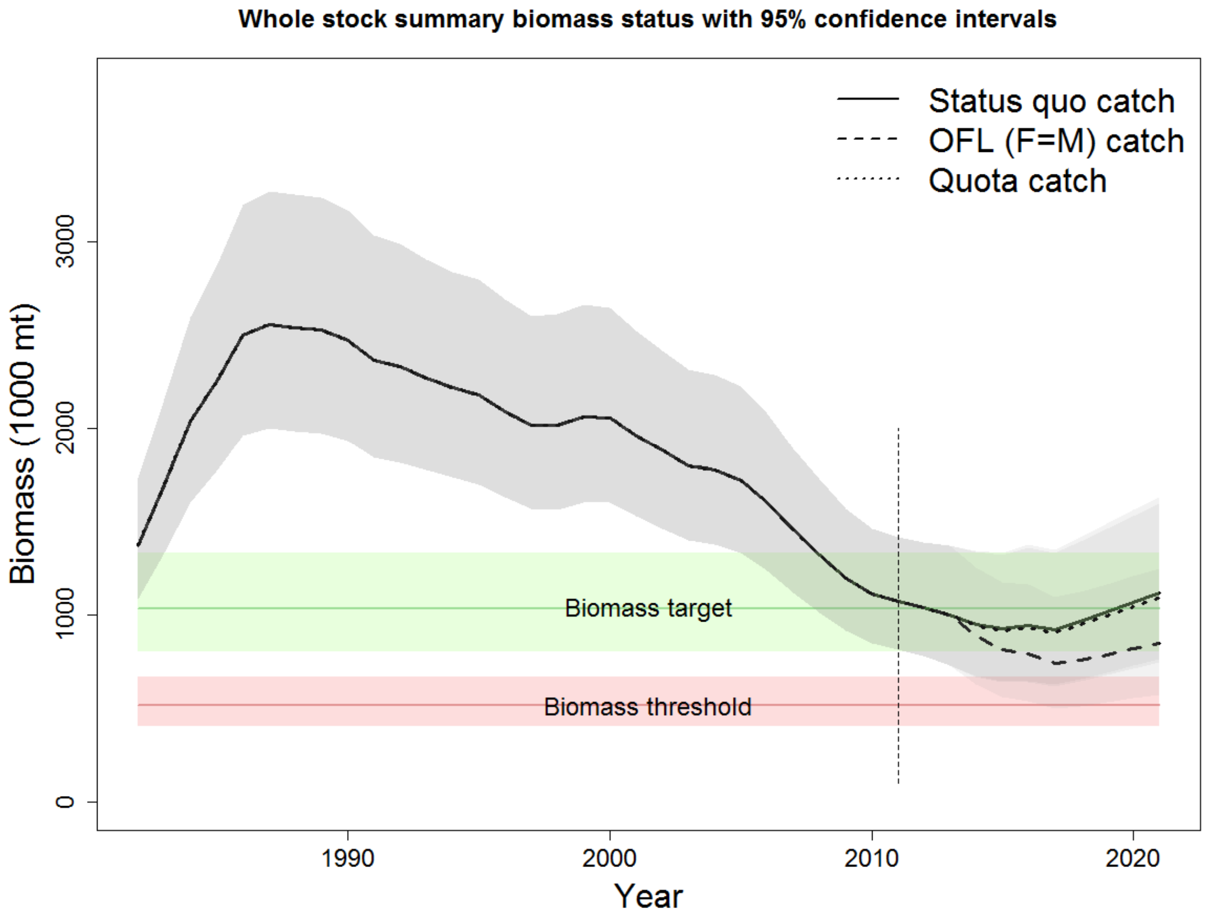


Figure A90. Summary biomass and 95% confidence intervals including projections for the whole stock, relative to biomass reference points. The dashed vertical line marks the terminal model year, 2011.

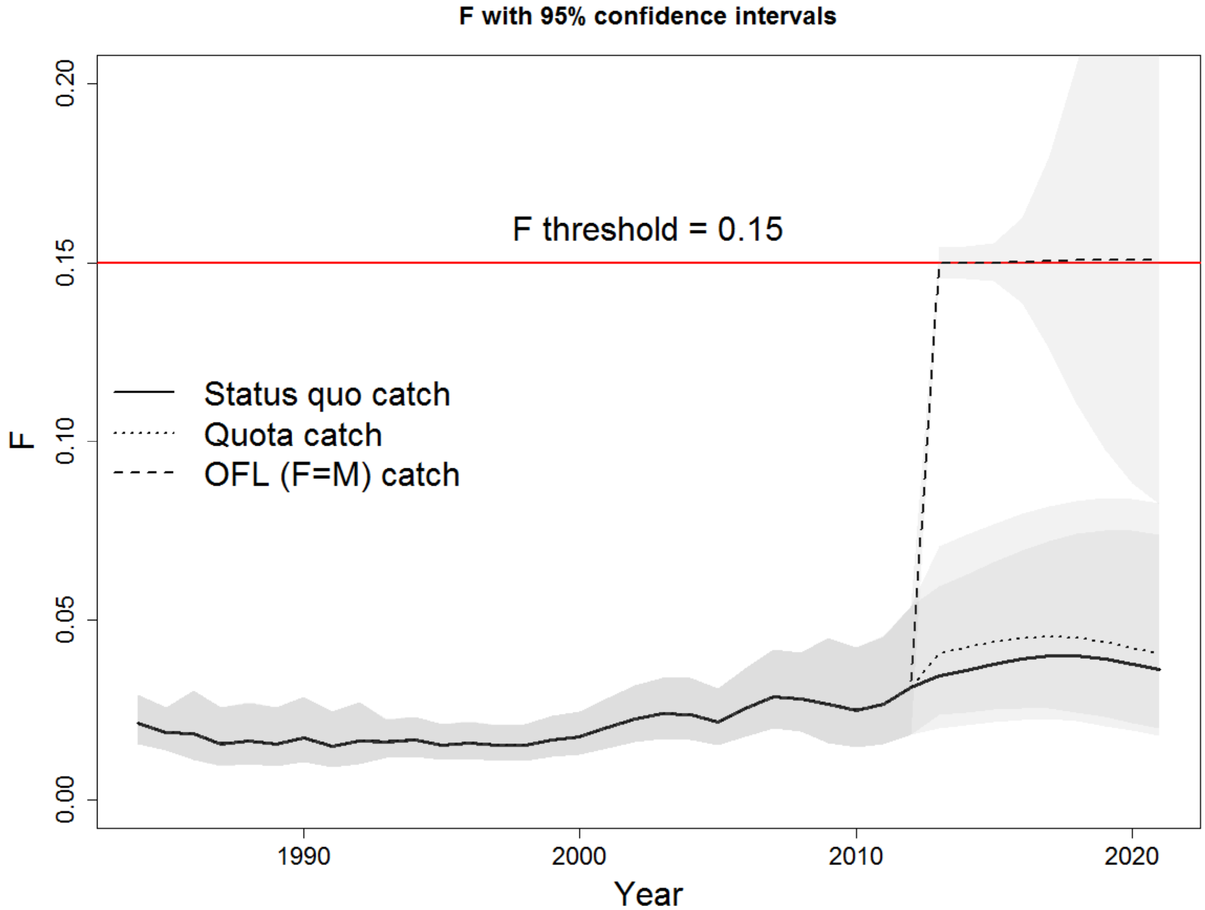


Figure A91. Annual fishing mortality and 95% confidence intervals including projections for the whole stock, relative to reference points.

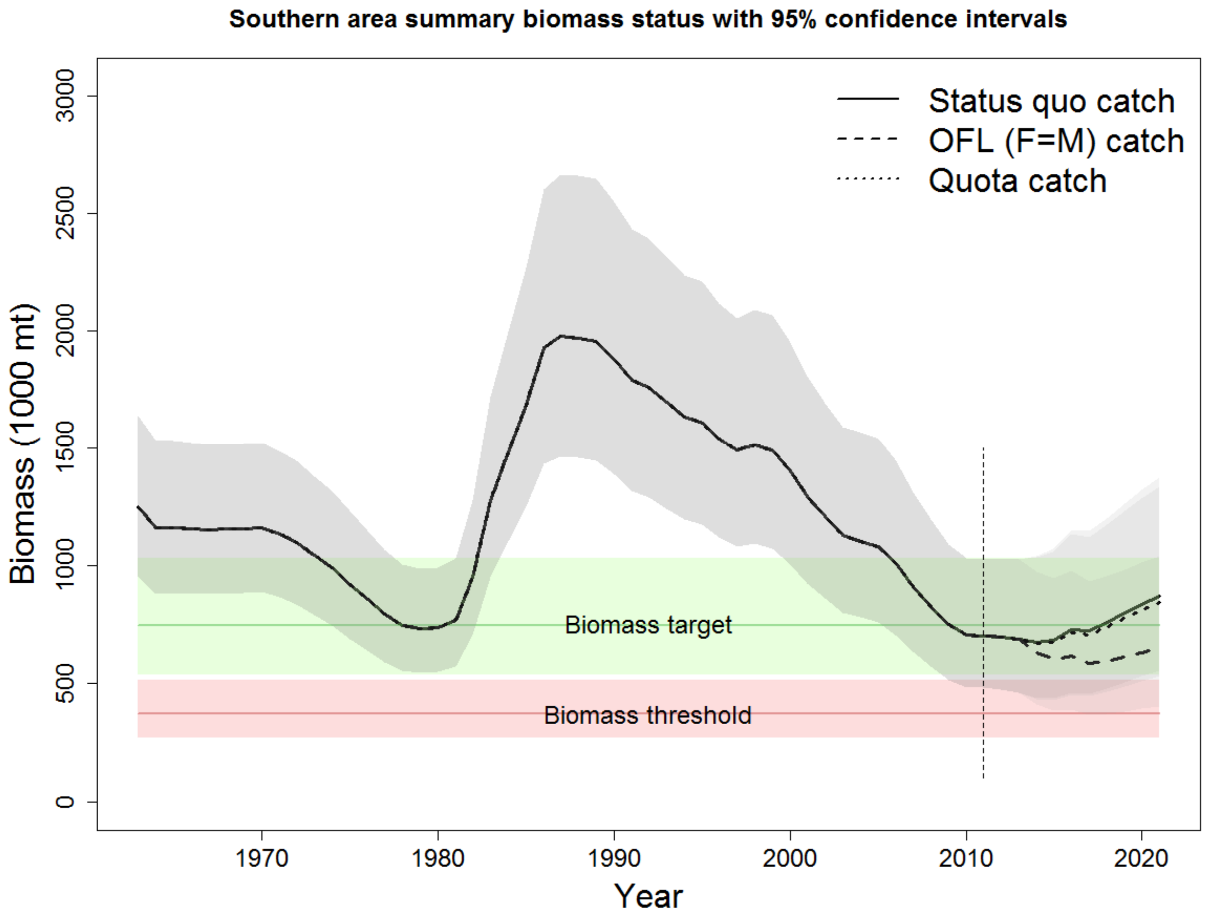


Figure A92. Summary biomass and 95% confidence intervals including projections for the southern area, relative to possible biomass reference points. The dashed vertical line marks the terminal model year, 2011.

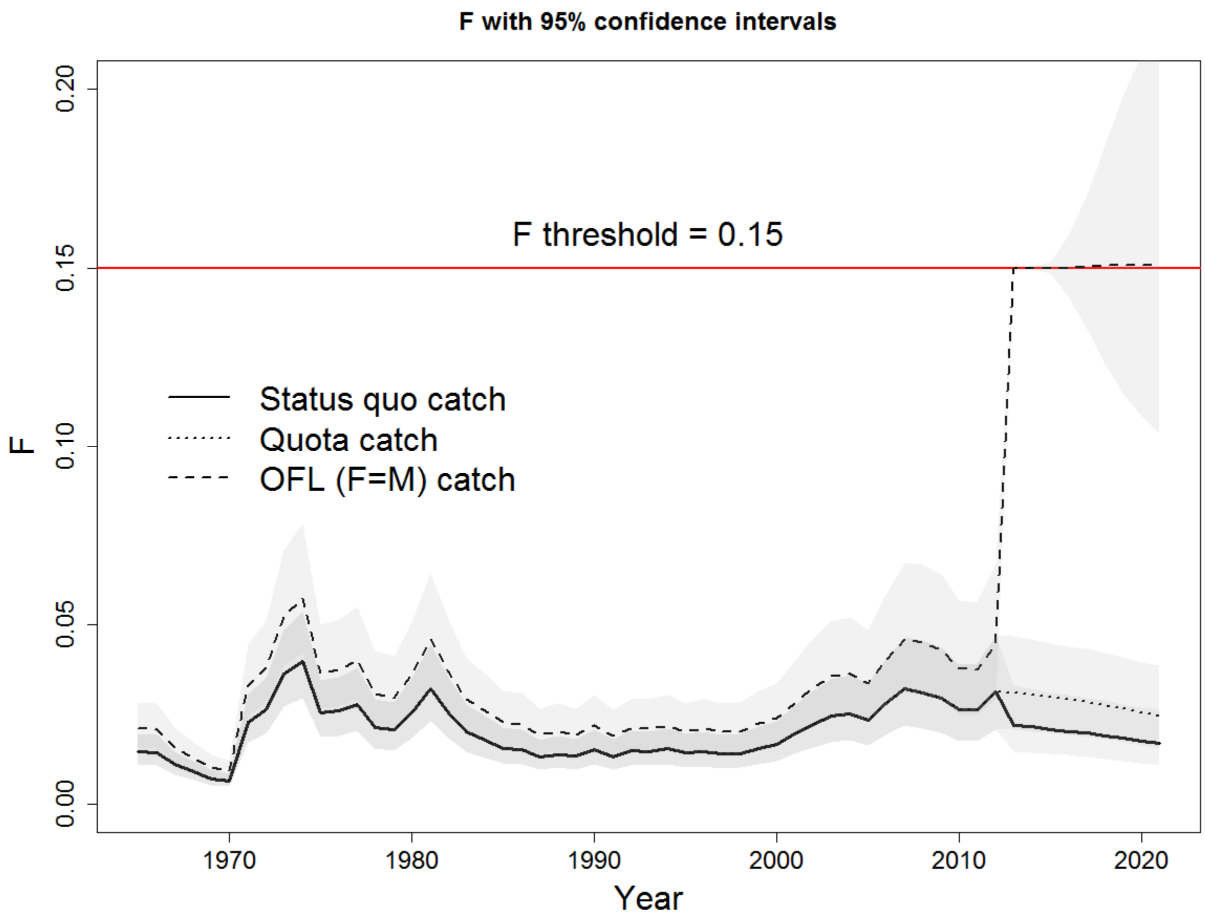


Figure A93. Annual fishing mortality and 95% confidence intervals including projections for the southern area, relative to reference points.

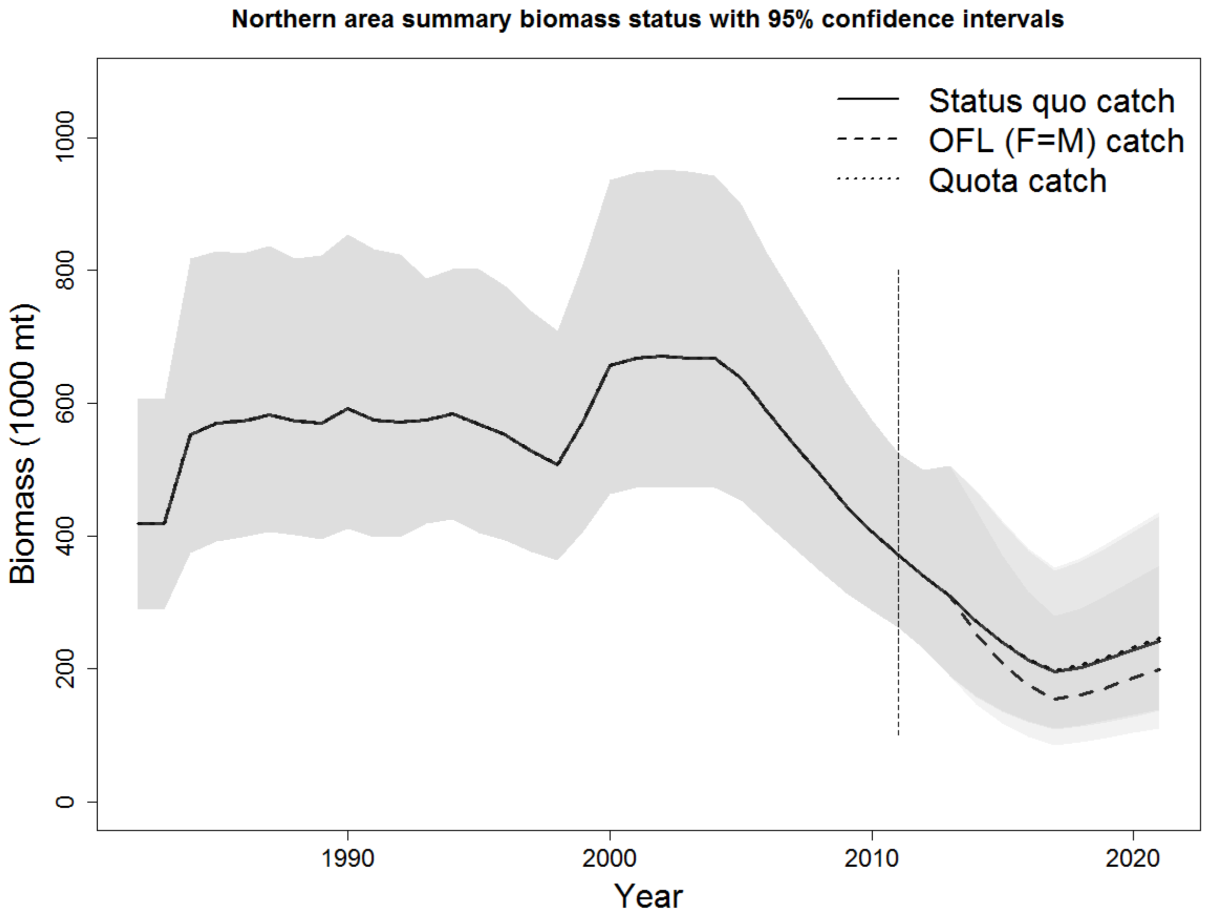


Figure A94. Summary biomass and 95% confidence intervals including projections for the northern area, relative to possible biomass reference points. The dashed vertical line marks the terminal model year, 2011.

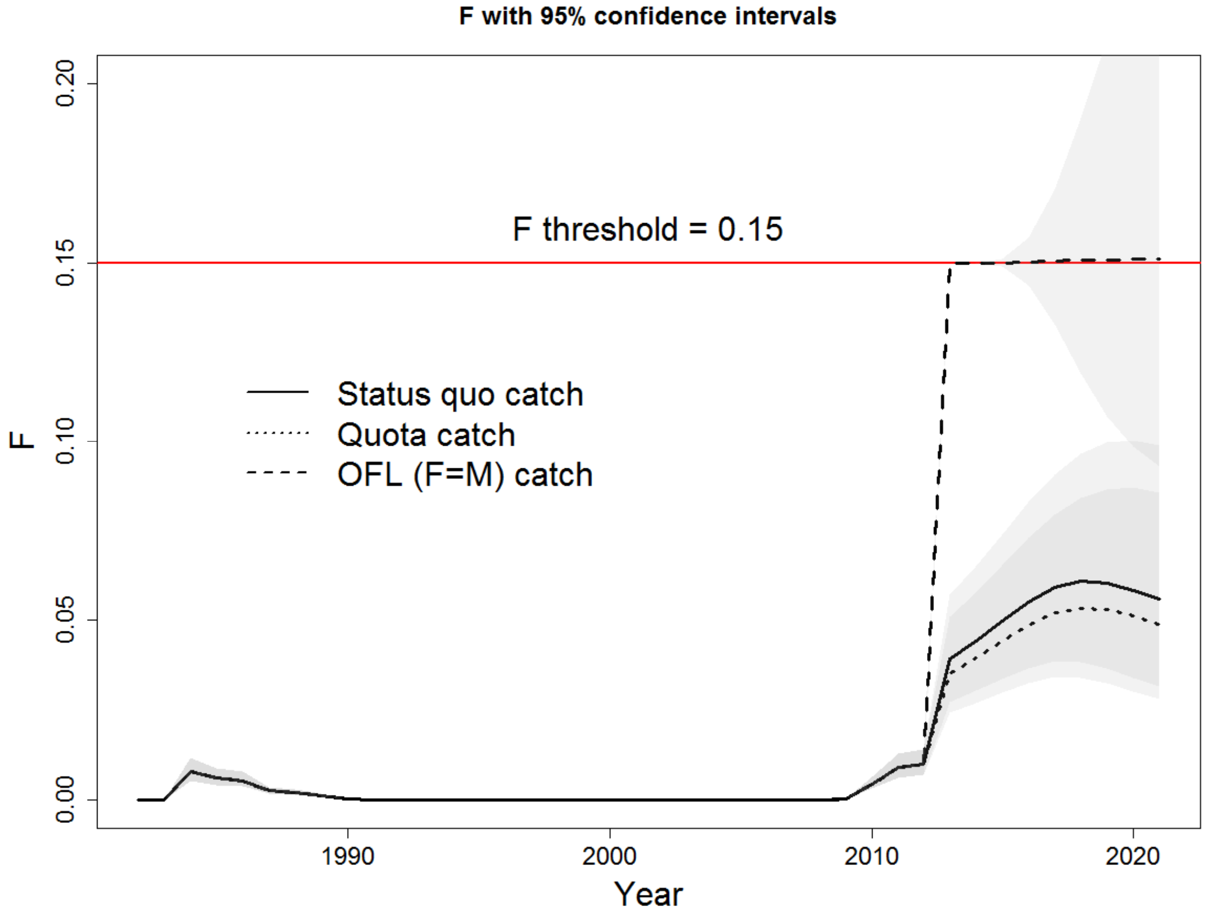


Figure A95. Annual fishing mortality and 95% confidence intervals including projections for the northern area, relative to reference points.

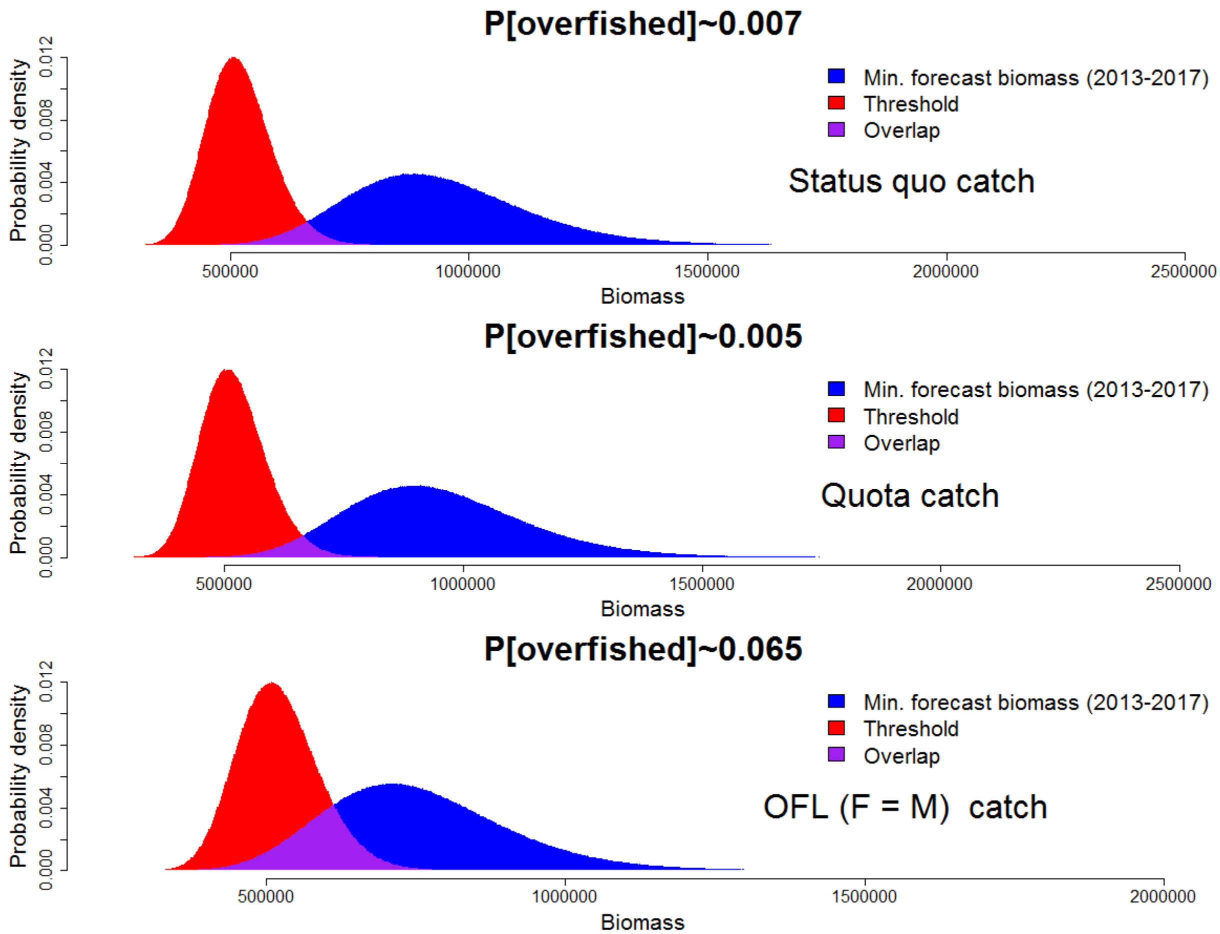


Figure A96. The maximum probability of the whole stock being overfished in any one of the next five years (2013 – 2017), given the three projection scenarios.

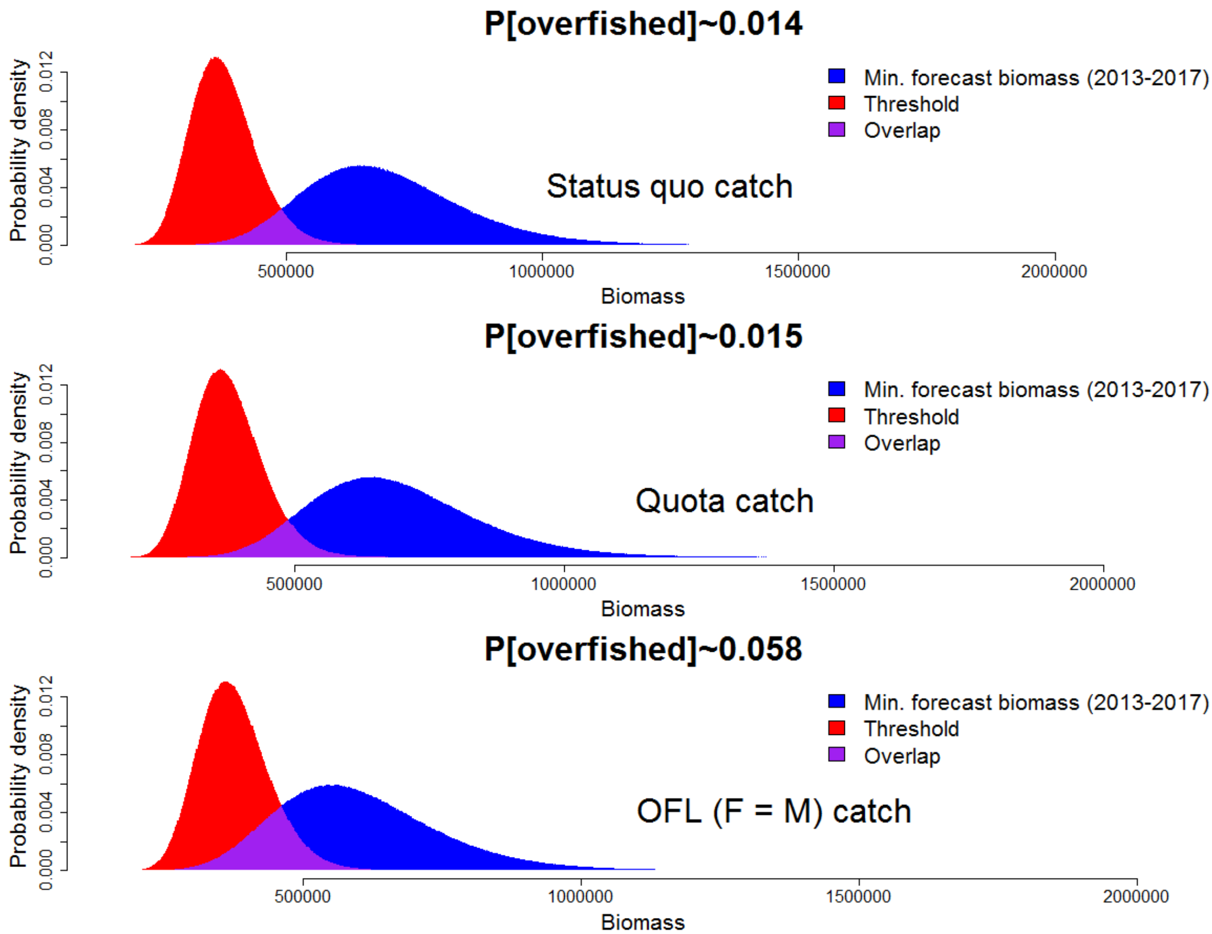


Figure A97. The maximum probability of the southern area being overfished in any one of the next five years (2013 – 2017), given the three projection scenarios.

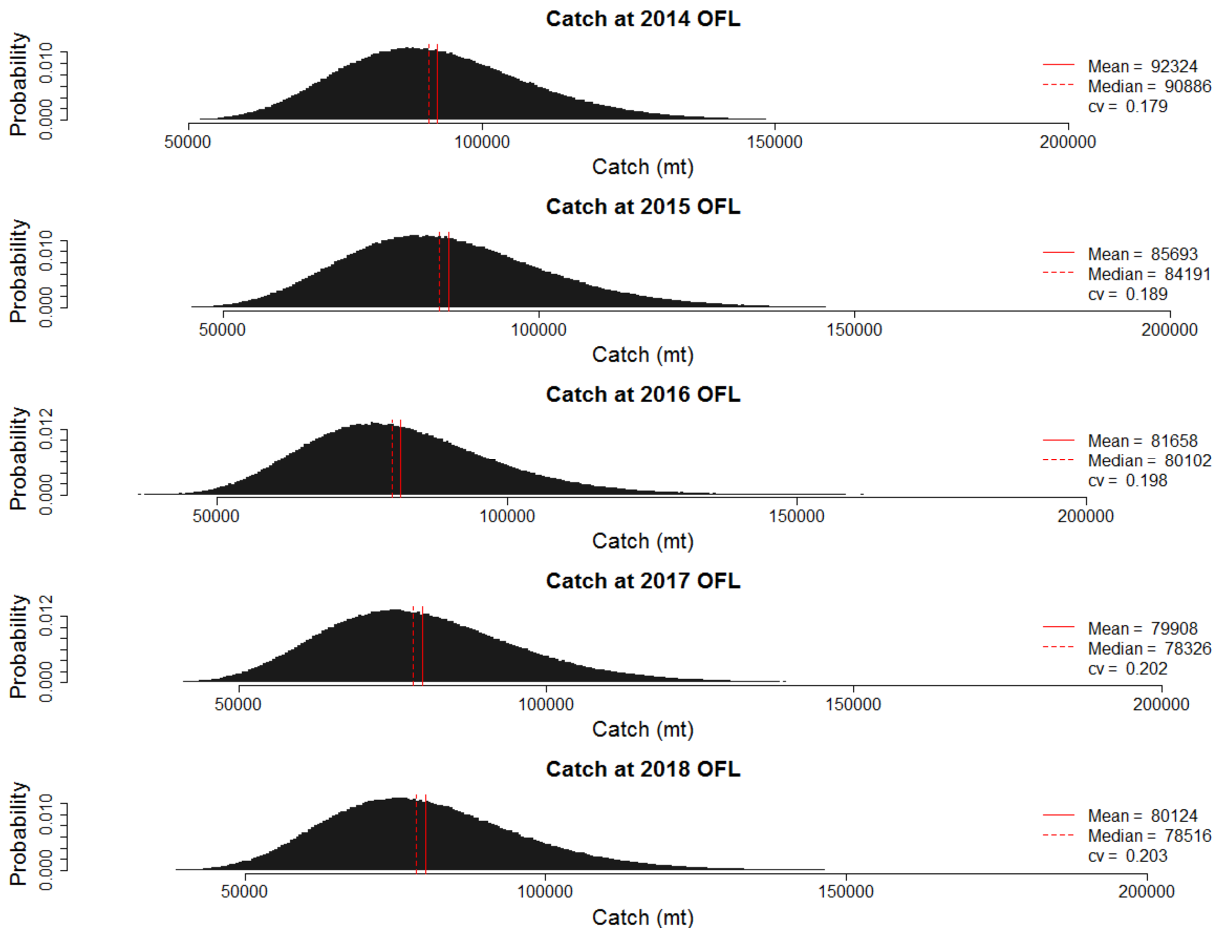


Figure A98. Probability distribution of the catch at the OFL for each of the next five years in projection for the whole stock.

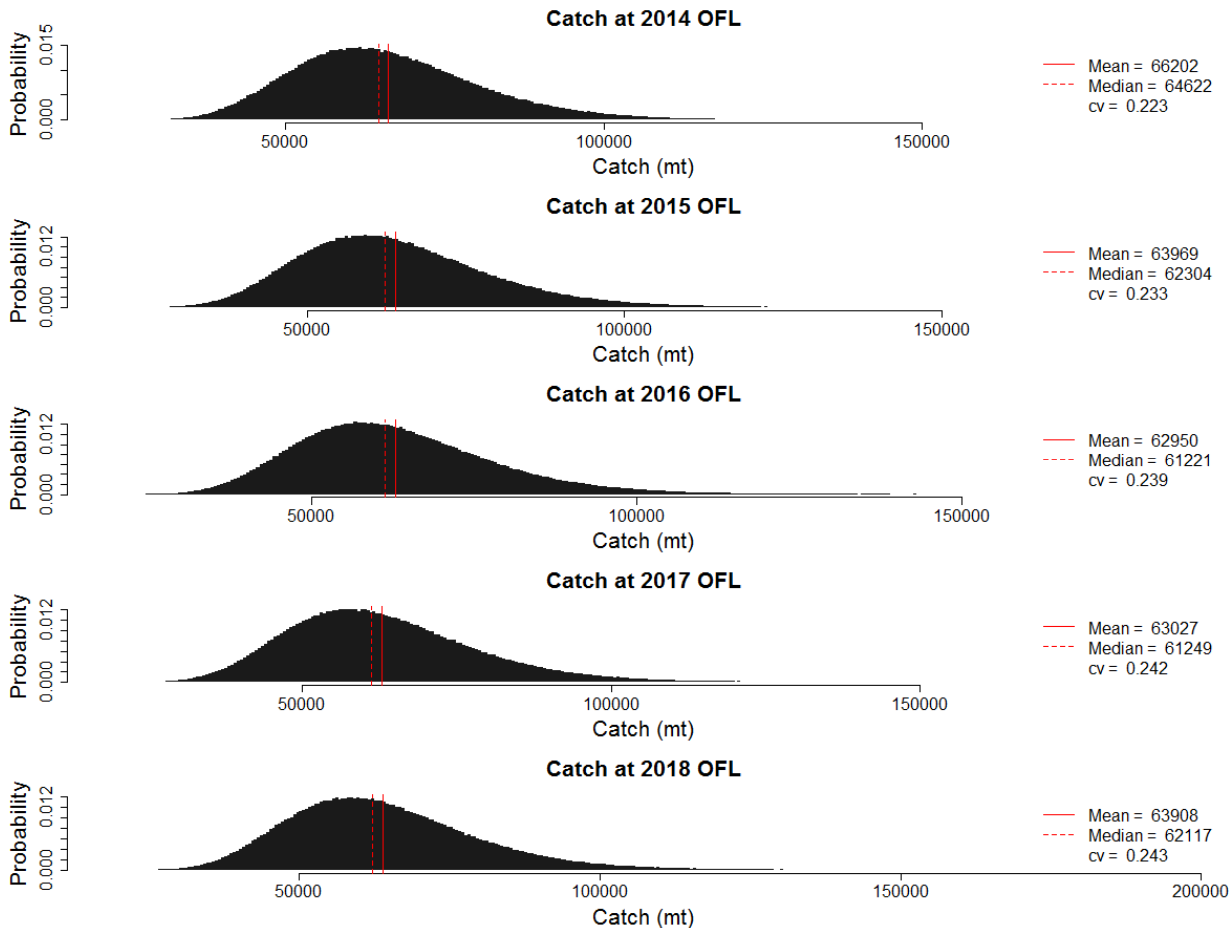


Figure A99. Probability distribution of the catch at the OFL for each of the next five years in projection for the southern area.

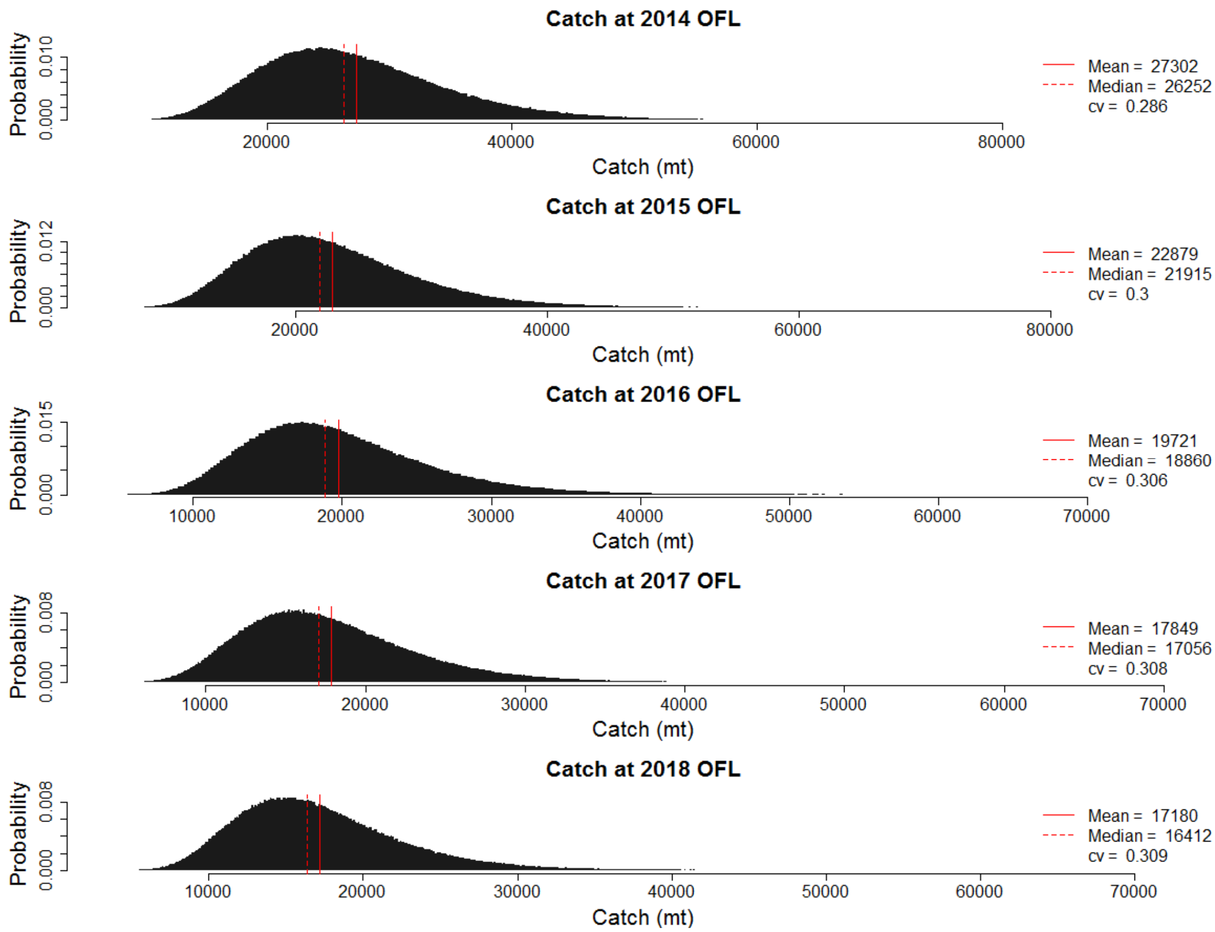


Figure A100. Probability distribution of the catch at the OFL for each of the next five years in projection for the GBK area.

A. Stock assessment appendices for Atlantic Surfclams in the US EEZ

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Appendix A1: Surfclams in New York and New Jersey state waters[1]

[1]**Many thanks to Jeff Normant of the New Jersey Division of Fish and Wildlife and Debra Barnes and Jennifer O'Dwyer of the New York State Department of Environmental Conservation for data and assistance with this report.**

The states of New York and New Jersey support surfclam fisheries in their territorial waters not covered by the NEFSC clam survey. The two states have carried out their own annual or semi-annual surveys of the resource since 1992 and 1988, respectively. Commercial and survey data from state waters are important in this assessment of the federally managed EEZ stock given the biological linkage between state waters and the EEZ, the productivity and importance of fisheries in state waters, and the possibility of environmental effects in southern surfclam habitat. New York and New Jersey state waters have historically been excellent habitat for surfclams, but there is evidence of declining recruitment to the population in both states. The percentage of landings harvested from state waters has been falling since 2001 (Figure 1).

The New York and New Jersey state surveys

The New Jersey State survey is conducted annually by the New Jersey Department of Environmental Protection from a commercial clam vessel with a commercial hydraulic dredge, most recently the F/V Ocean Bird. The survey has been conducted since 1988, and has followed a stratified random sampling protocol since 1994. The survey area is divided into regions covering the whole New Jersey coast, and each region has 3 one mile wide strata, parallel to the coast, covering surfclam habitat out to the 3-mile limit of state waters (Figure 2). Each survey does between 250 and 330 five minute tows, measuring the tow volume in bushels, then counting and measuring a known volume of surfclams for population estimates and length frequencies. Grab samples of the sediment are also taken.

Data from the state of New Jersey available for this appendix includes annual state surfclam survey numbers and lengths through 2012 and grab samples for juvenile surfclams through 2011. Surfclam landings from New Jersey state waters are available from 1989-2012.

The New York surfclam survey is conducted by the New York Department of Environmental Conservation approximately every three years. They use a commercial clam vessel, most recently the F/V Ocean Girl, with a hydraulic dredge. The survey area is divided into four regions which span the southern shore of Long Island. The three westernmost regions are subdivided into three mile wide strata (Figure 3). The most recent surveys have taken place in the summer or fall, had an average of 236 stations, and used a random stratified sampling technique. Tows are three minutes long, the total volume of each tow is measured in bushels, and half a bushel of surfclams from each tow is measured and counted for population estimates and length frequencies. A picture of the dredge used is shown in Figure 4.

Data from New York State are from the 2002, 2005, 2006, 2008 and 2012 state surfclam surveys. Total numbers, densities and length frequencies are available for all years and ages are available for all years except 2012. Surfclam landings from New York state waters are available through 2011.

Results

Both states have seen a significant decrease in the population of surfclams (Figure 5). The peak population of surfclams in New Jersey in recent years seems to have occurred in 1996, a few years before the peak in biomass in the EEZ in 1998-1999. The data available to us from New York do not go back far enough to see evidence of a concurrent population peak.

Despite the decline in numbers of clams in surveys since 2002, landings in New York stayed remained relatively high through 2006 (Figure 6). There was a very large harvest limit set in 2004 (930,000 bushels) and it was almost reached, making the landings from New York from that year almost double what they had been in years before. In 2010 and 2011, landings were around 200,000 bushels annually.

Surfclam landings for human consumption from New Jersey state waters have fallen from a high of about 700,000 bushels in 2003 to less than 100,000 in 2005 and to near zero levels since 2006. Since the early 2000s, a few tens of thousands of bushels of surfclams have been harvested annually from “prohibited waters” (where they are not allowed to be sold for human consumption due to contamination) to be sold as bait (Figure 7). About a third of the surfclam standing stock in New Jersey is in prohibited waters (Figure 8).

In the 2000s, the length composition of surfclams in New Jersey was narrow and composed of only larger surfclams, indicating a lack of new recruitment. However, recent survey data shows some smaller clams recruiting to the population (Figure 9). The 2011 NEFSC clam survey also showed evidence of some recruitment off New Jersey and New York.

Surfclams from the New York surveys conducted in 2005 and 2006 were larger on average than those collected in 2002, yet some smaller clams were seen in the 2008 and 2012 surveys, mirroring the bump in recruitment seen in the New Jersey and NEFSC surveys (Figure 10).

Surfclam densities have historically been high in the inshore areas surveyed by New Jersey and New York states compared to offshore areas south of Georges Bank surveyed by NEFSC (Figure 12). However, inshore densities appear to be falling recently towards levels typical of more unproductive offshore areas (Figure 11). However, the comparisons in Figure 11 are approximate due to differences in dredge design, capture efficiency and size selectivity. Numbers have been falling in all strata in New Jersey (Figure 13).

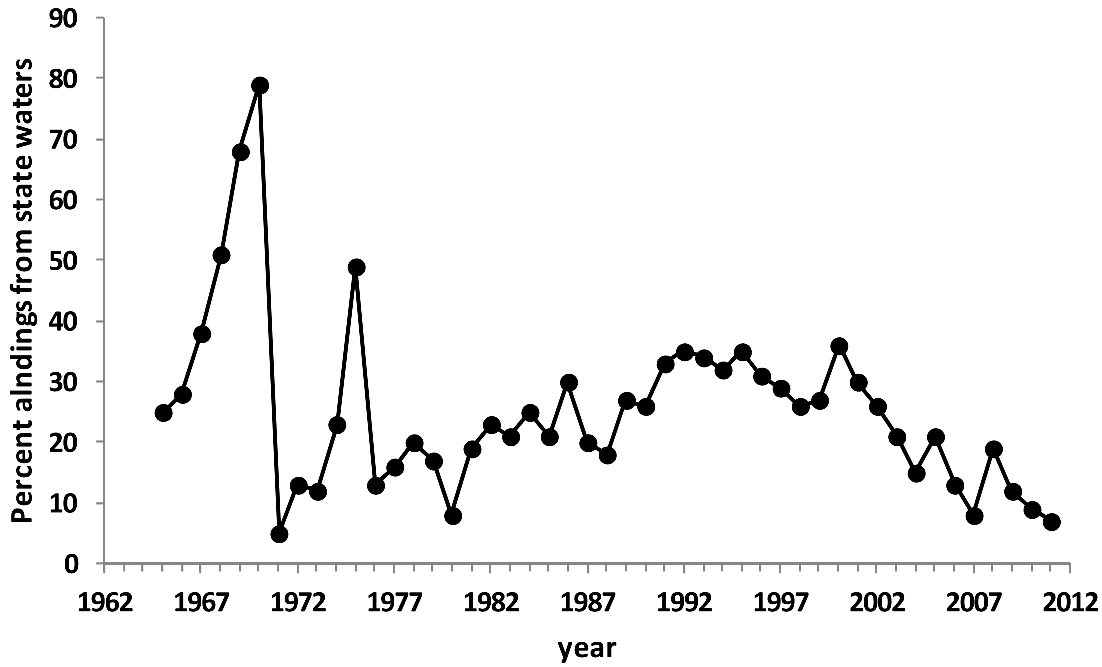
Recently it appears surfclams in New York and New Jersey have been unable to resupply their aging populations with new recruits. This could be happening because there is not enough successful spawning occurring and the supply of larvae is not there, or because smaller surfclams are dying before they are available to a survey or commercial dredge.

In New Jersey, grab sample data collected regularly since 1994 from the area of the survey show that juvenile surfclams are setting successfully out of the plankton (Figure 14). Some years have been better than others with occasional larger sets such as the ones seen in 2005 and 2009, a typical pattern for bivalve recruitment. This data does not show any downward trend in juvenile surfclams that might explain the decline in older surfclams of fishable size.

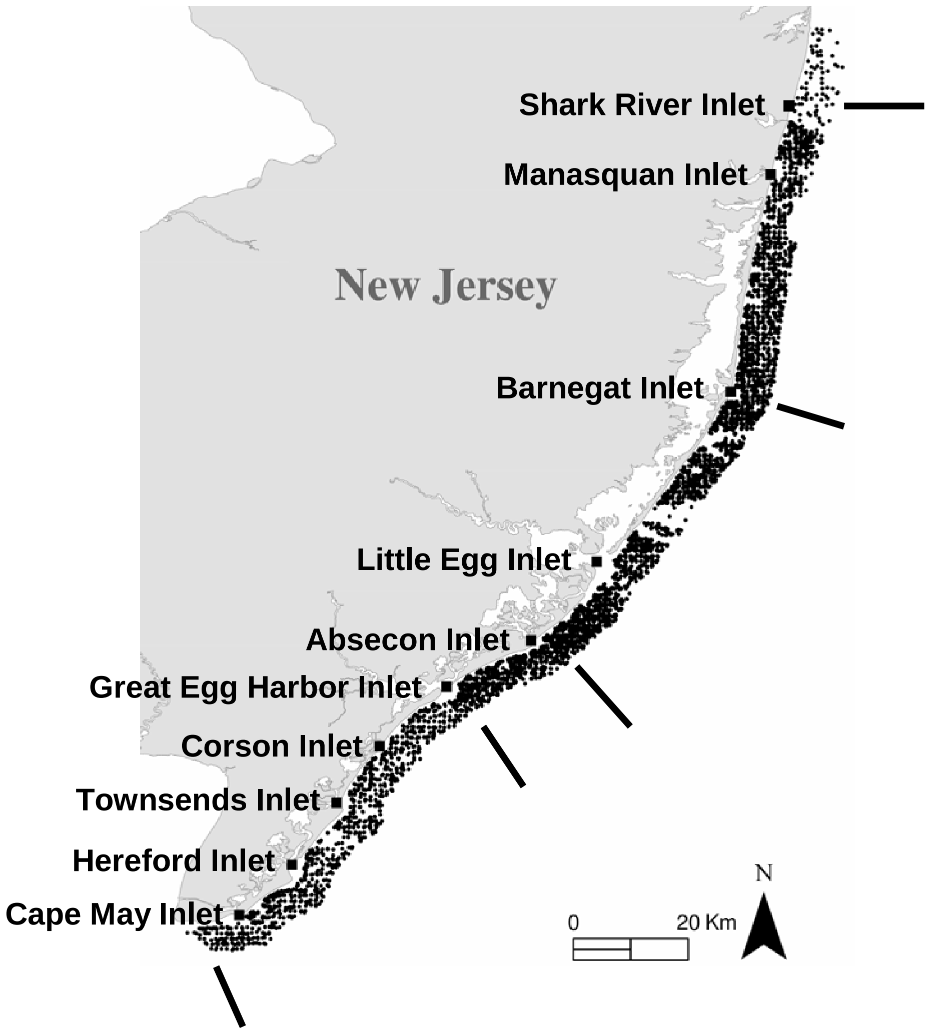
Surfclam age frequencies from the New York surveys in 2002, 2005, 2006 and 2008 (Figure 15) show that surfclams of all ages are present with recognizable ~1996, ~1991 and ~1988 year classes which can be followed. The 2008 data also reflect the recent recruitment seen in the survey size frequencies in both New York and New Jersey. Age data from the Long Island region of the NEFSC survey are not available, but recognizable year classes seen in the New Jersey region included one in 1992.

Length-at-age data from the New York surveys (figure 16) indicate there was no significant change in growth rate from 2002 through 2008, but all regions and strata were lumped together so spatial changes may be masked.

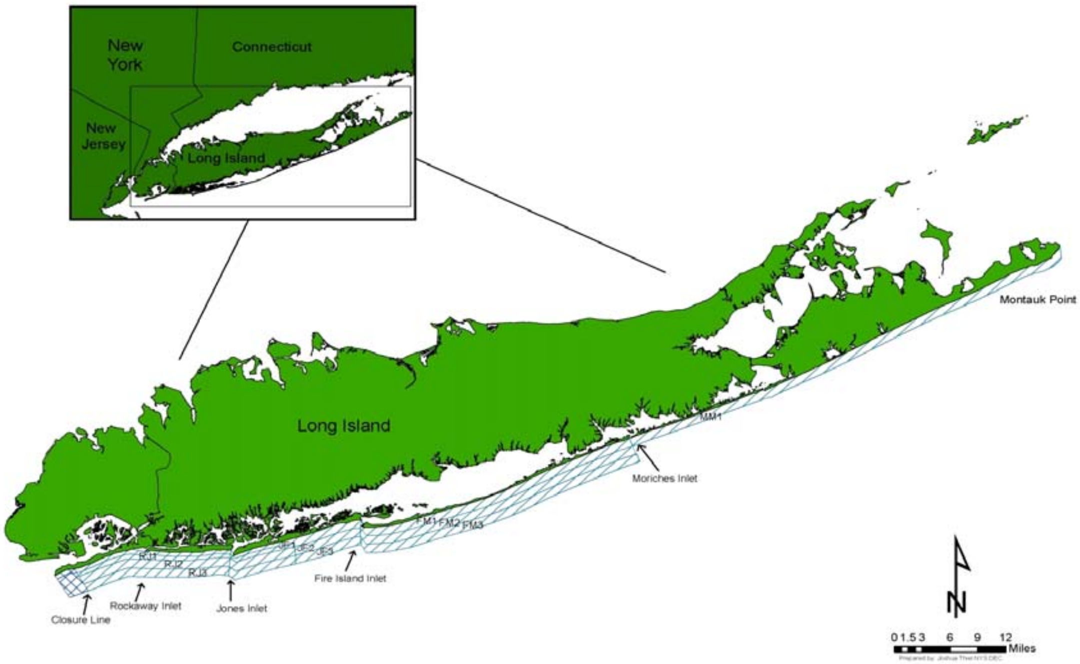
Exploitation rates (landings / survey abundance) were calculated for surfclams in both NJ and NY state waters (Figure 17). The data suggest that exploitation rates in NJ waters decreased from about 4% in 1996 to 2% in 1997-1998 then increased to about 6% in 2002 before falling to zero by 2005 as the fishery for human consumption all but ceased. The limited data for NY indicate that exploitation increased from 2002 to 2008 (landings data were not available for NY in 2012). These simple exploitation rates provide useful information about relative trends in fishing mortality, but they assume all the surfclams in the path of the survey dredge are captured, which is almost never true. The capture efficiency of a clam dredge is almost always less than one, so exploitation rates calculated here for surfclams in state waters are probably overestimated. NJ landings for use as bait were excluded because surfclams for bait are harvested in contaminated areas outside of the survey region.



Appendix A1, Figure 1. Percentage of total surfclam landings that came from state waters, which are mostly New Jersey and New York with small amounts from New England.

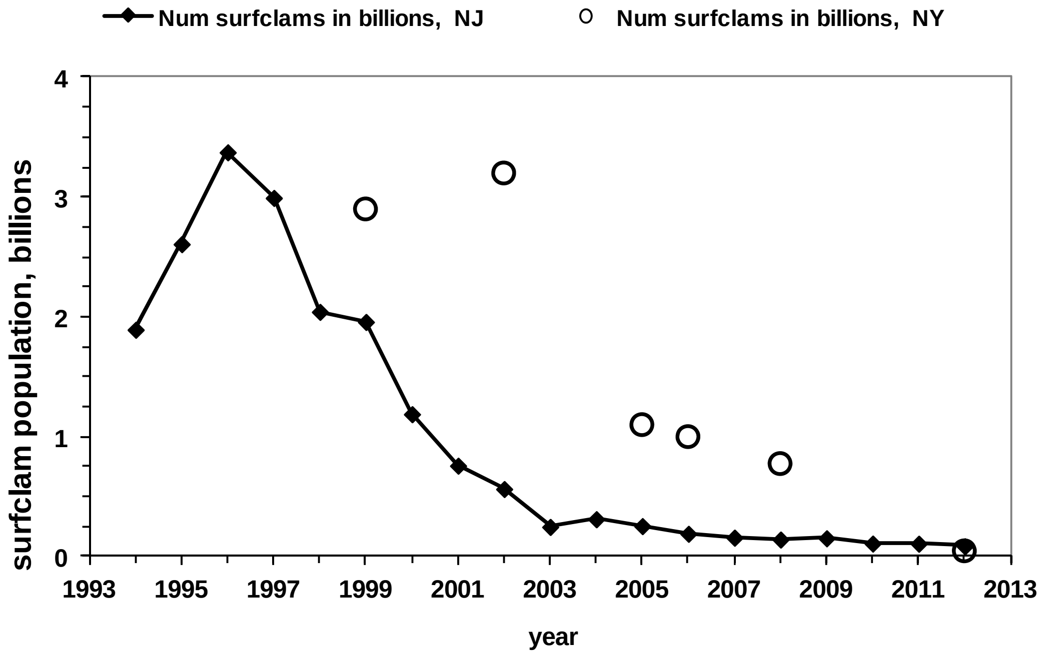


Appendix A1, Figure 2. Map showing the sampling regions for the NJ state survey, and station locations 1988-2008. Within each region there are three along-shore depth strata one mile wide. Map courtesy of Jeff Normant, NJDEP.

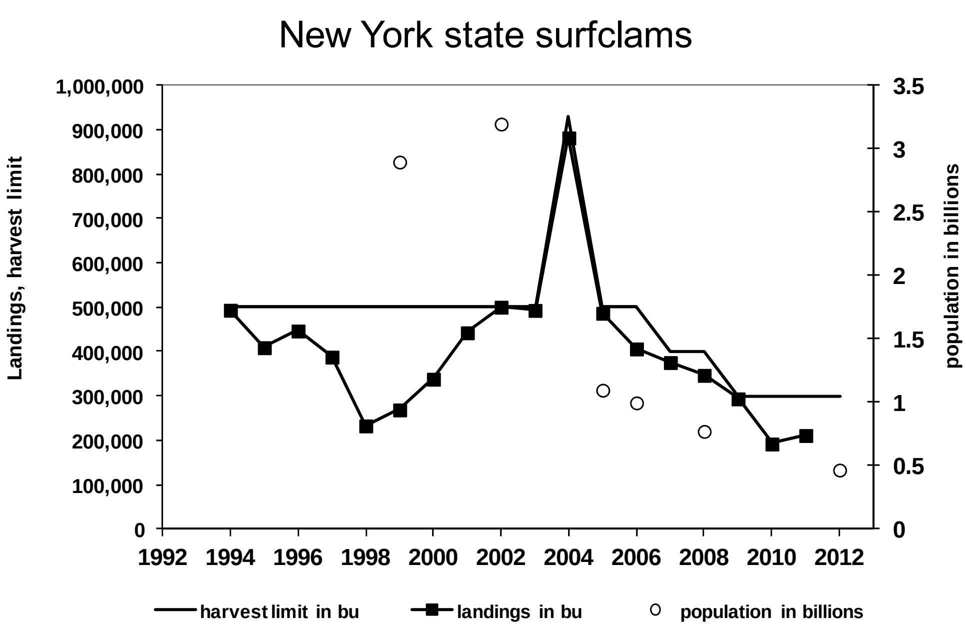


Appendix A1, Figure 3. Map showing New York state sampling regions from west to east: RJ, JF and FM, which each have 3 depth strata, and MM which has one depth stratum. Map courtesy of Wade Carden, NYSDEC.

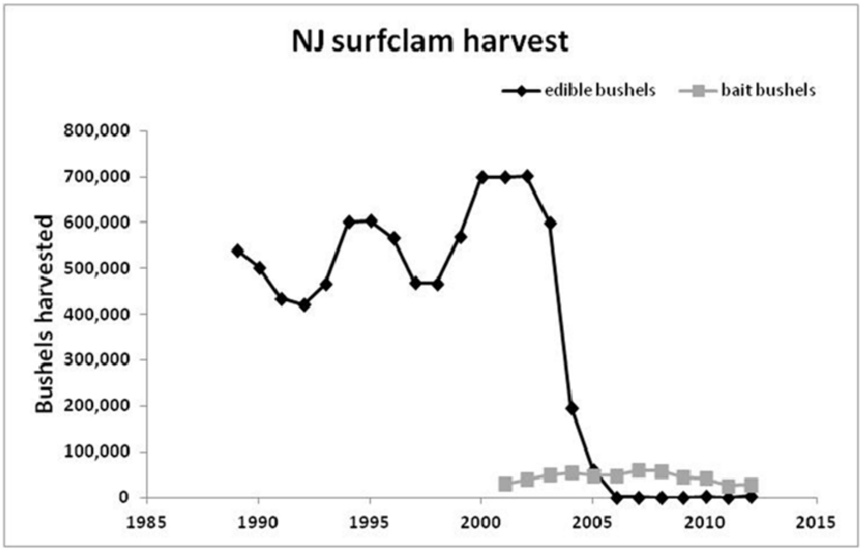
Appendix A1, Figure 4. The inshore commercial clam dredge used for the New York surveys. Photo courtesy of Jeff Normant, NJDEP; William Burton, Versar, Inc.; and Beth Brandreth, USACE.



Appendix A1, Figure 5. Survey-based population estimates for surfclams in New Jersey and New York from years when there was random stratified sampling.

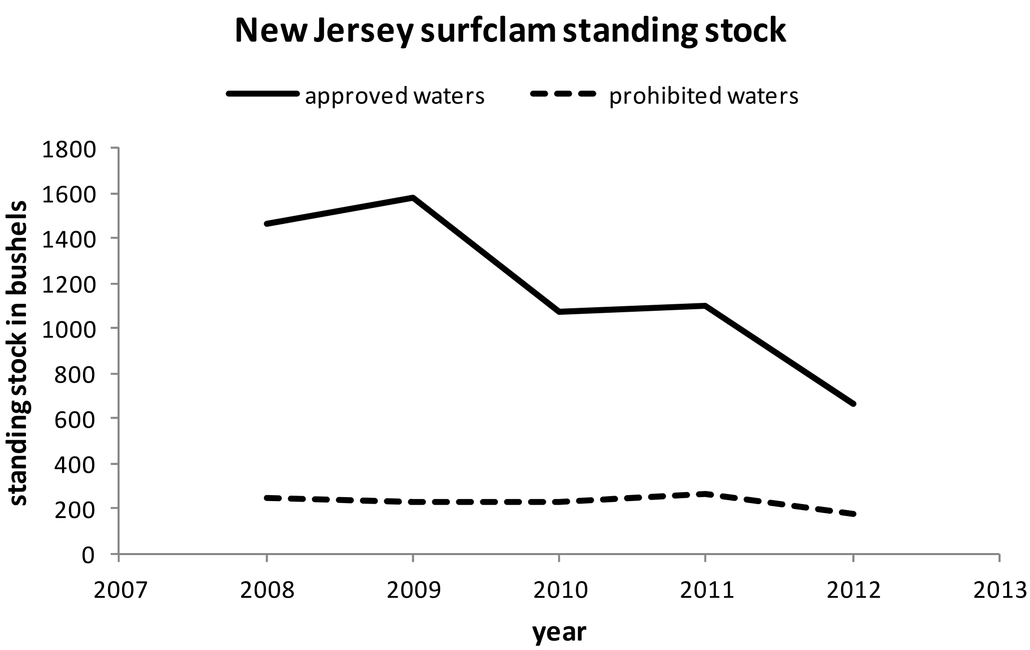


Appendix A1, Figure 6. Landings, harvest limit and population of surfclams in New York state waters. Landings and harvest limit are scaled to the left axis and population is scaled to the right axis. The harvest limit was raised to 890,000 bushels for one year in 2004.

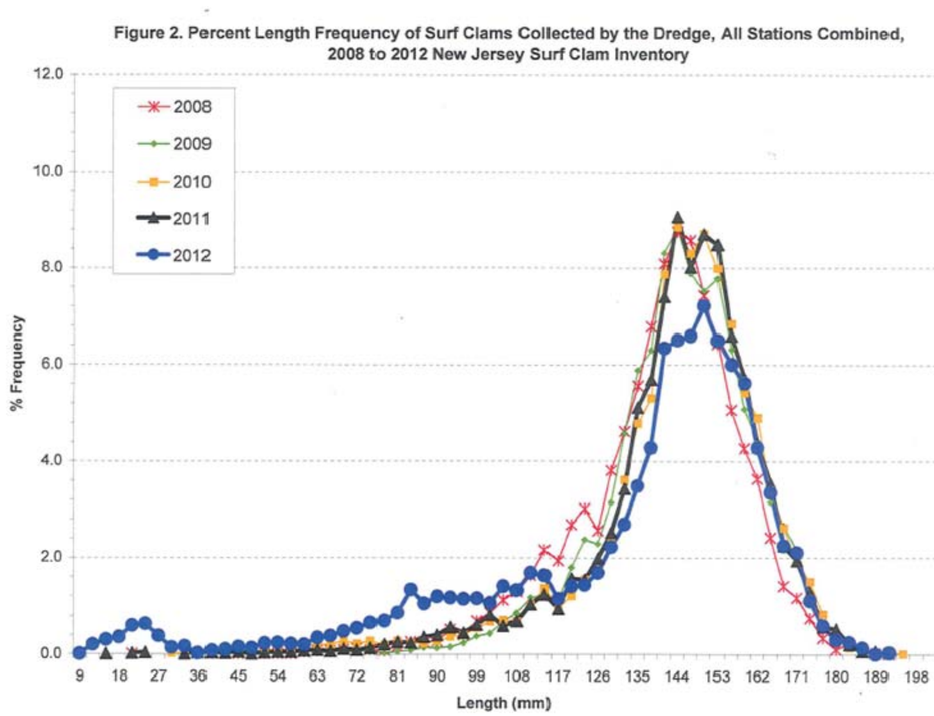


Quota for 2010-2011 season: 55,296 bushels (season OCT –MAY)
Quota for 2011-2012 season: 49,152 bushels

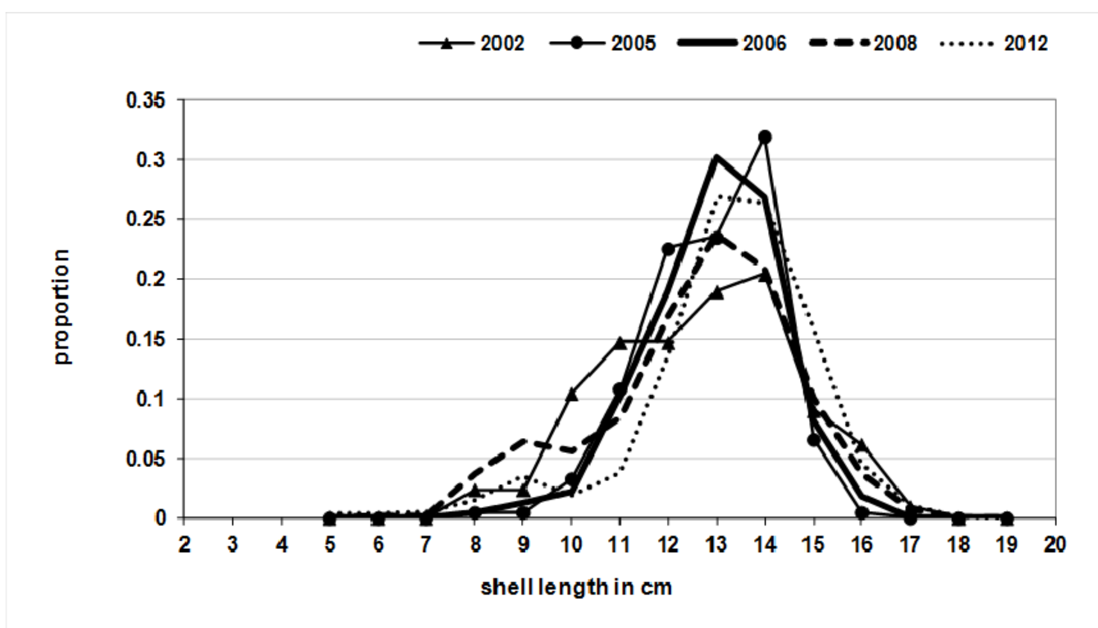
Appendix A1, Figure State - 7. Bushels of surfclams harvested from New Jersey "approved" (surfclams for human consumption) and "prohibited" (surfclams for bait only) waters.



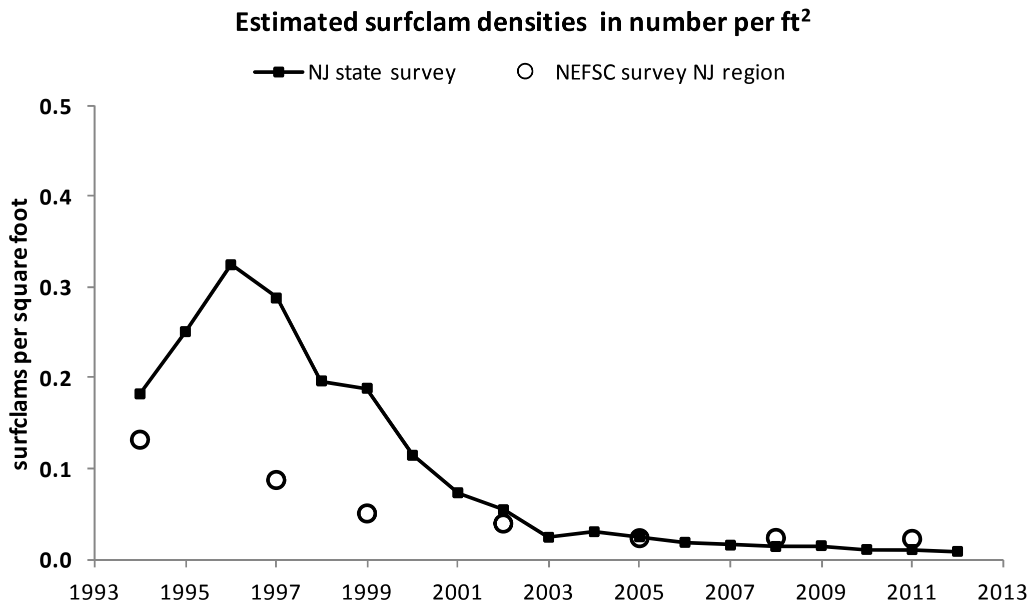
Appendix A1, Figure 8. Standing stock in industry bushels from New Jersey state waters. Clams from approved waters can be sold for human consumption, while clams from prohibited waters are sold for bait only.

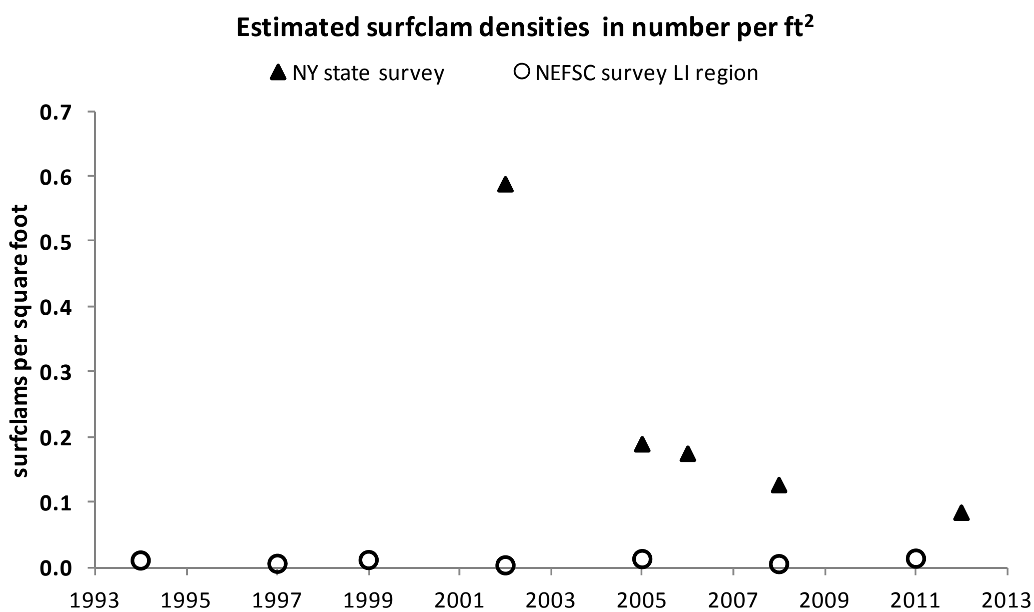


Appendix A1, Figure 9. Length frequencies from the 2008-2012 annual New Jersey state surfclam surveys. Figure courtesy of Jeff Normant, NJDEP.

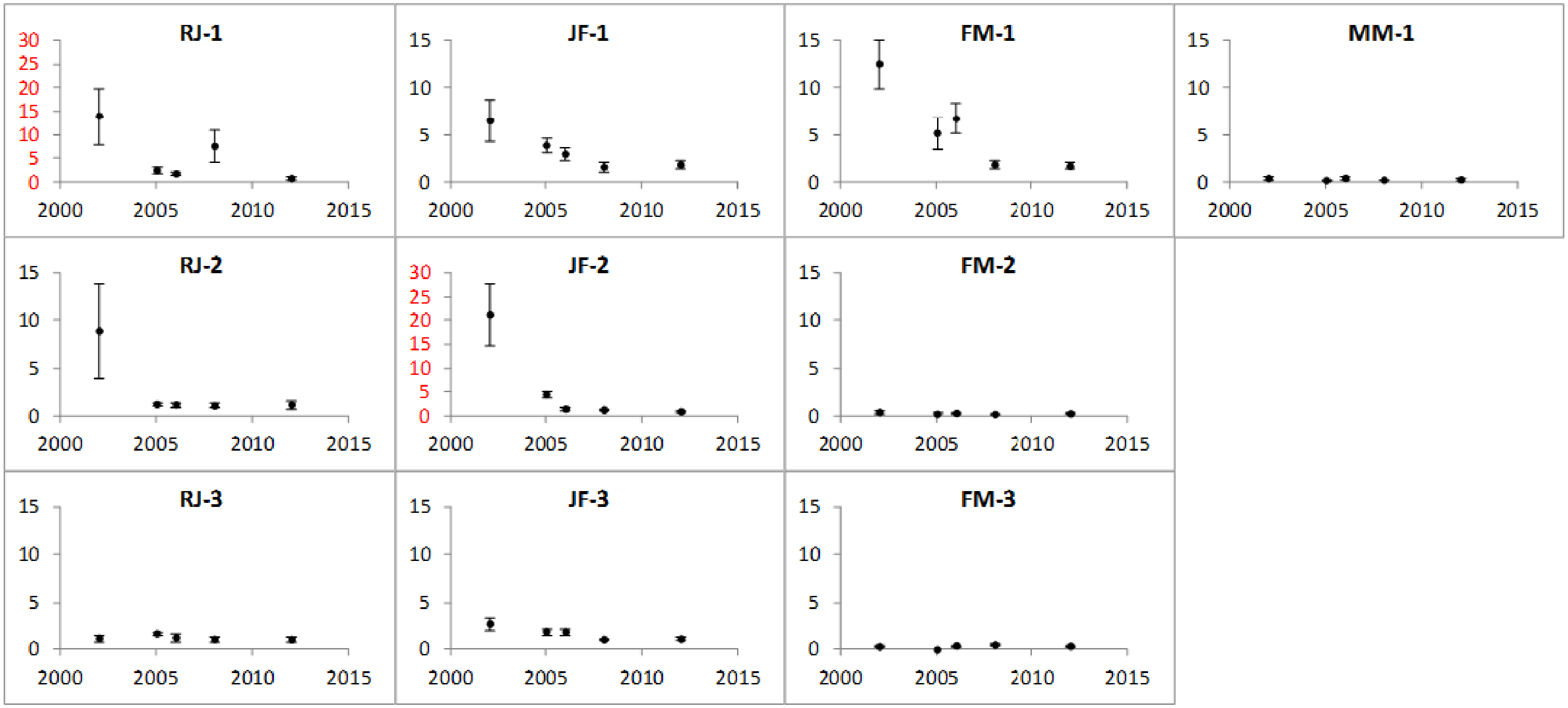


Appendix A1, Figure 10. Length frequencies from the 2002, 2005, 2006, 2008 and 2012 New York state surfclam surveys.

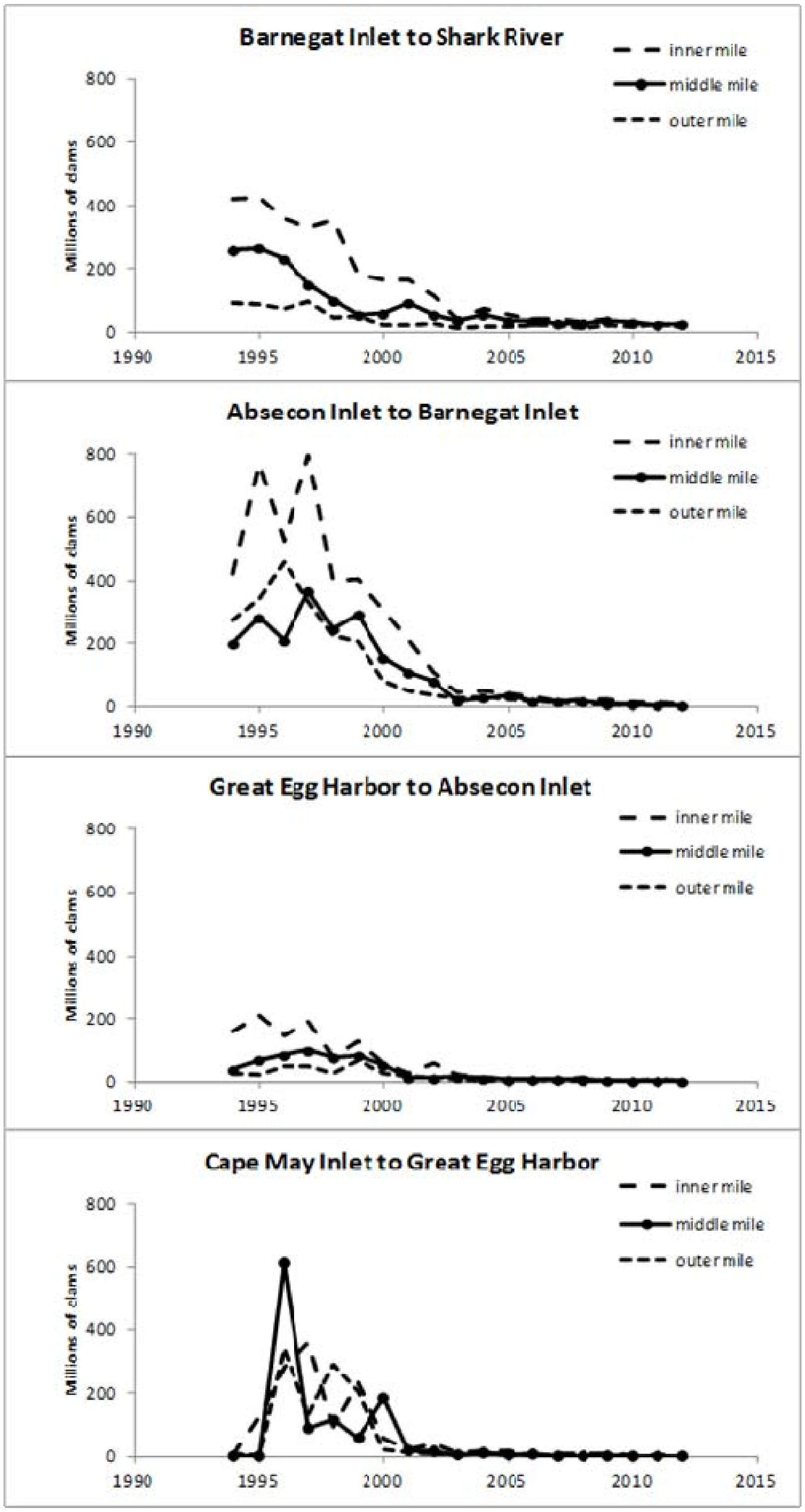




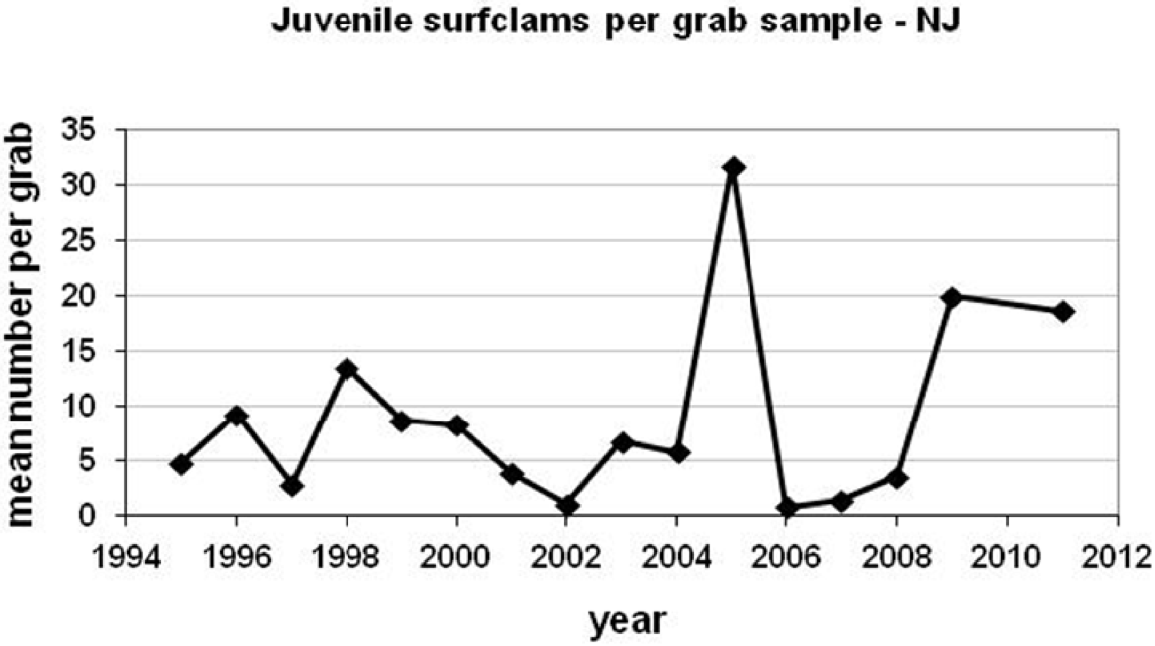
Appendix A1, Figure 11. A rough comparison of surfclam density estimates (total estimated number of clams over the area surveyed in square feet) from the NJ State survey and the NJ region of the NEFSC survey in federal waters (top) and the NY state survey and LI region of the NEFSC survey in federal waters (top). All sizes of clams were included, and an adjustment was made to the NEFSC data to account for a dredge efficiency of 0.256. No adjustments were made to the NY or NJ data. The comparisons are approximate due to differences in dredge design, capture efficiency and size selectivity



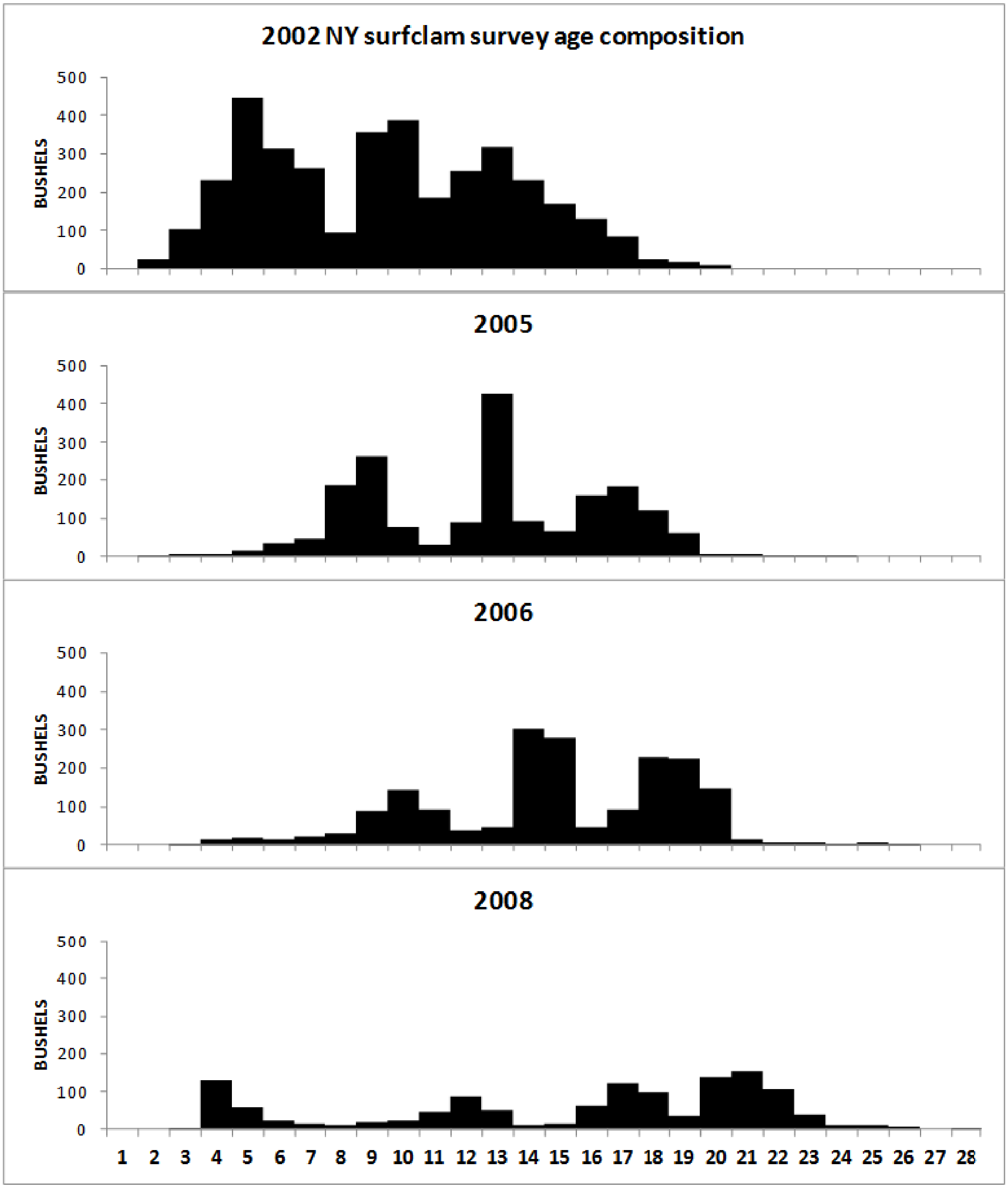
Appendix A1, Figure 12. New York State Surfclam Survey - Estimated density of clams, in individuals per m^2, per stratum by survey year. Strata cover the waters off the south side of Long Island. Plots are laid out in order with the left plots representing the westernmost strata, which are broken down into inner, middle and outer miles (numbers 1-3), covering the three-mile limit of State waters. The easternmost stratum has only the inner substratum. RJ = Rockaway Inlet to Jones Inlet, JF = Jones Inlet to Fire Island Inlet, FM = Fire Island Inlet to Moriches Inlet, MM = Moriches Inlet to Montauk Point.



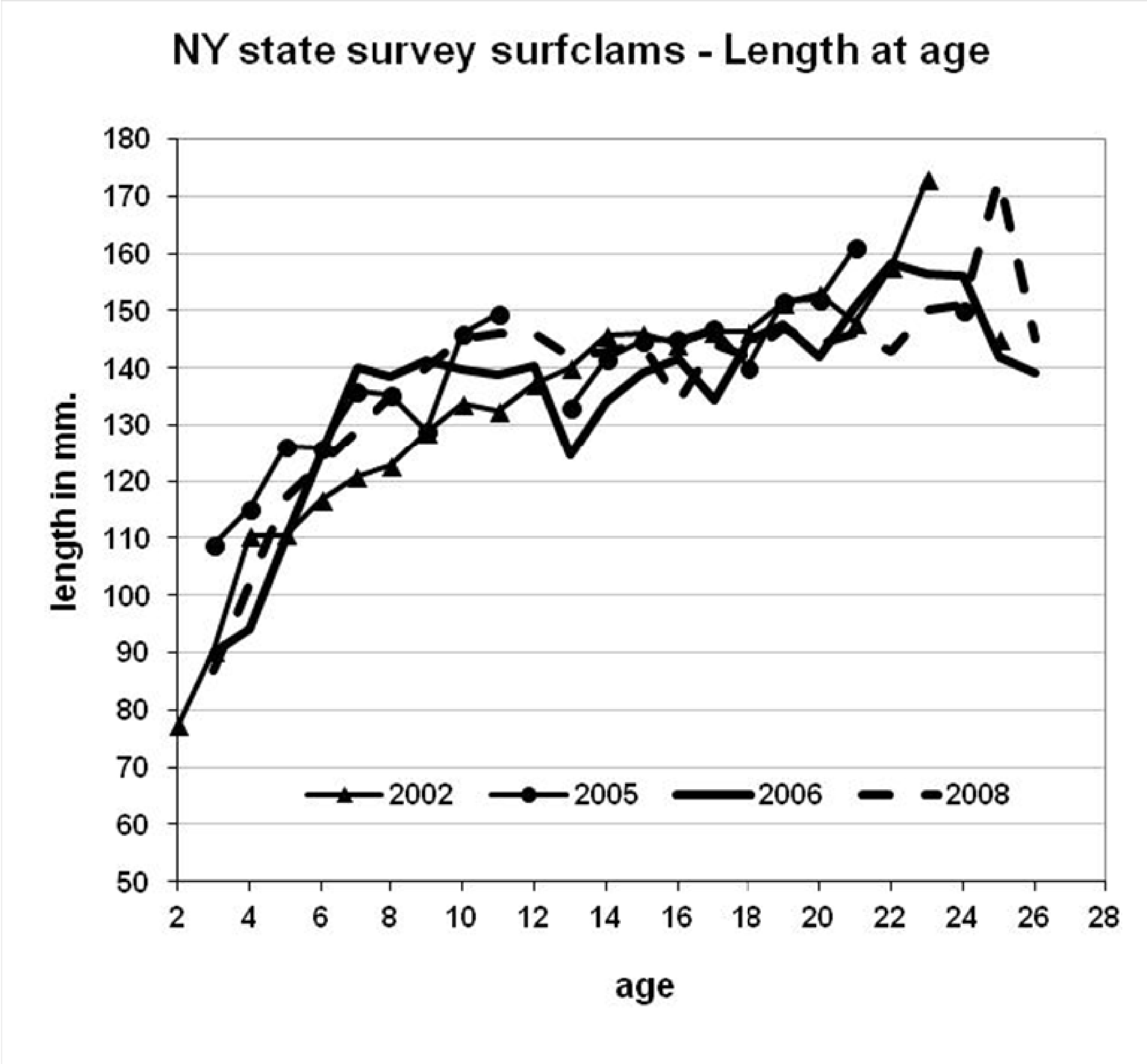
Appendix A1, Figure 13. New Jersey State survey - estimated number of clams per stratum by survey year. Plots are laid out in order with the top plot representing the northernmost stratum. Strata are further broken down into inner, middle and outer miles, covering the three-mile limit of State waters.



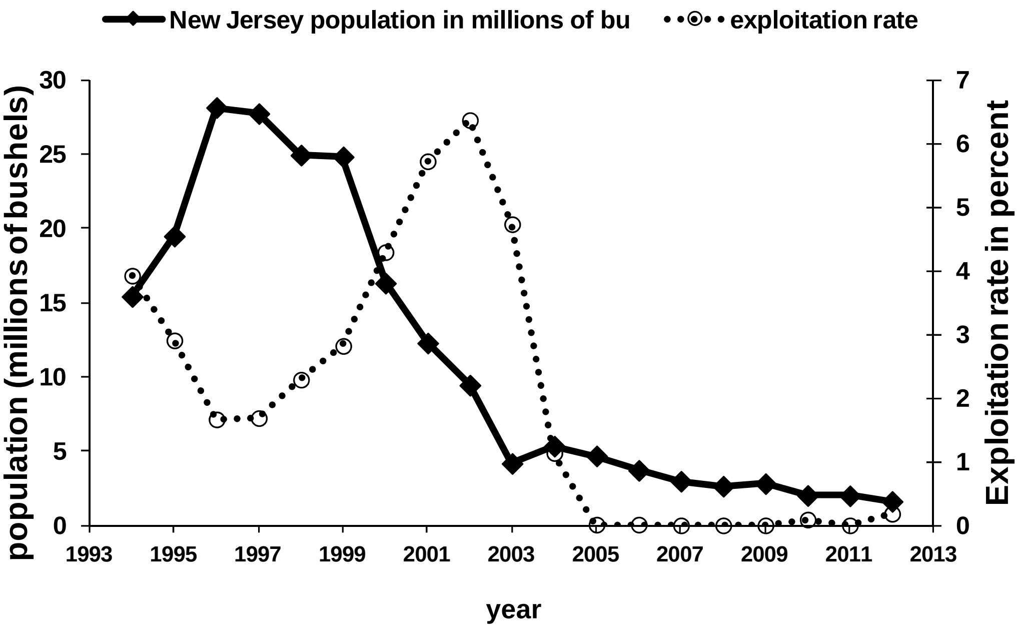
Appendix A1, Figure 14. As part of the annual survey, the state of New Jersey takes sediment grab samples, which contain recently settled juvenile surfclams. The clams are generally less than 10mm. About 300 grabs are taken every survey, and the area sampled is 1/10 of a square meter.

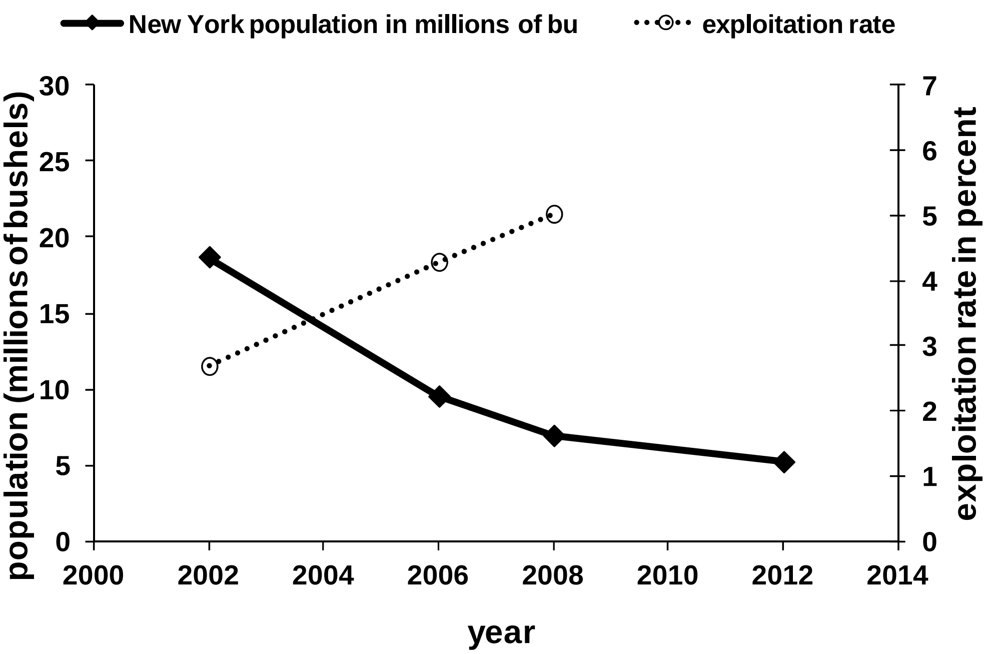


Appendix A1, Figure 15. Age compositions from the 2002, 2005, 2006 and 2008 New York State surfclam surveys, in bushels at age.



Appendix A1, Figure 16. Surfclam length at age from the 2002, 2005, 2006 and 2008 New York State surveys.

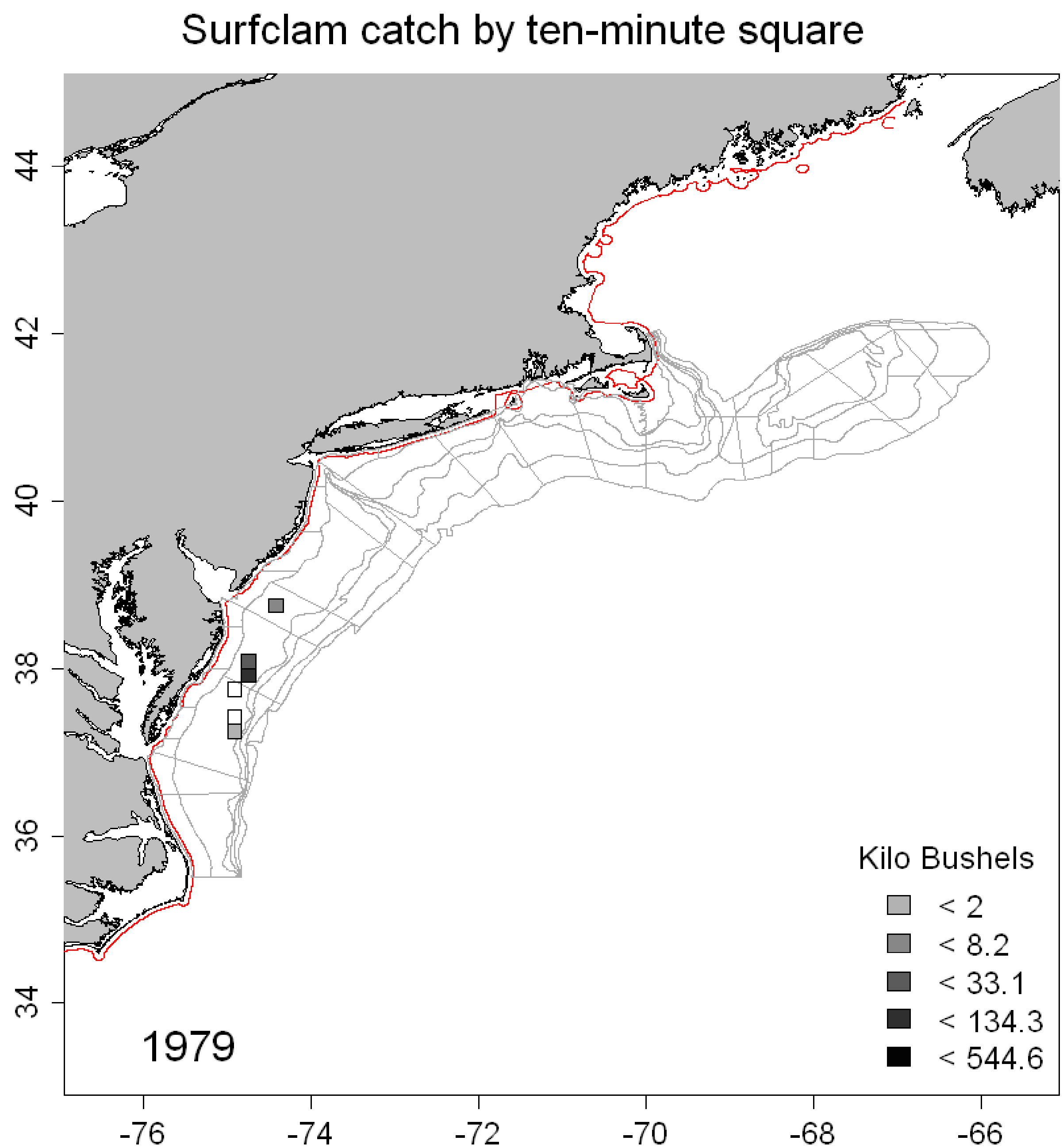


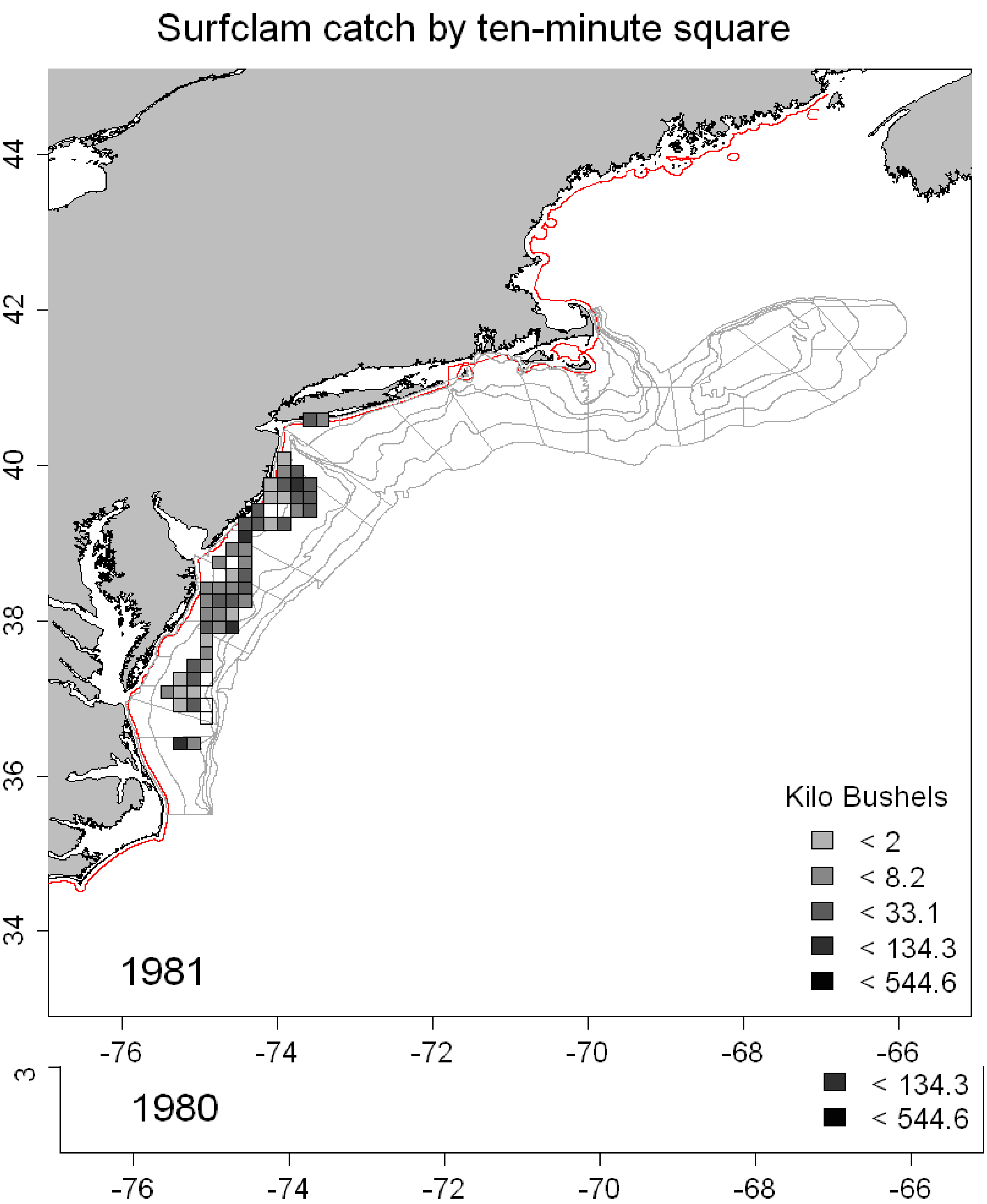


Appendix A1, Figure 17. Exploitation rates (expressed as landings as a percentage of estimated biomass) and population biomass for New Jersey (top) and New York state surfclams.

Appendix A2: Maps of commercial harvest through time

Appendix A2, Figure 1. Landings, time fished and LPUE by ten-minute square from 1979 – 2011 (Following pages).




Surfclam catch by ten-minute square
44
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34
1981
Kilo Bushels
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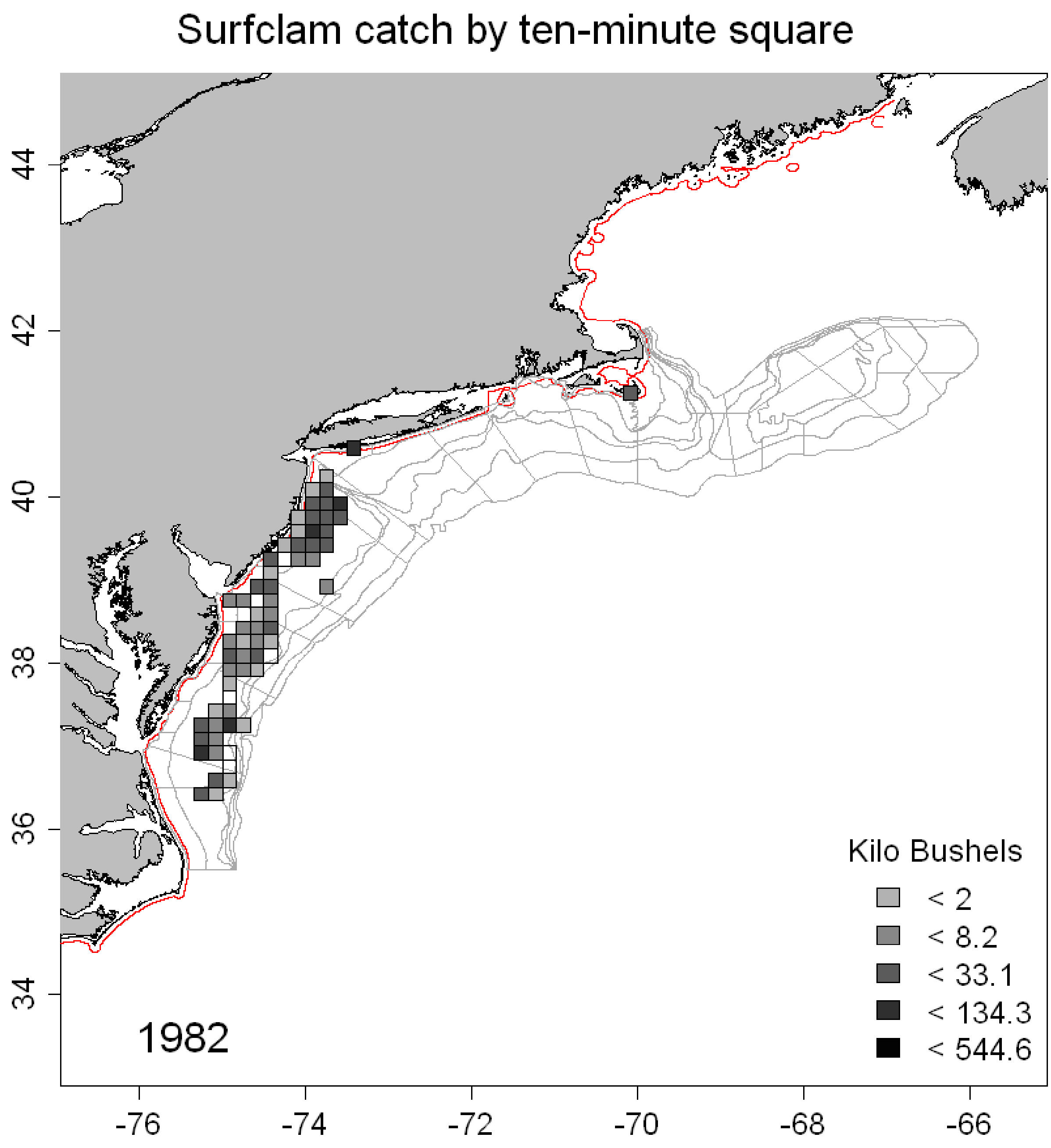
Surfclam catch by ten-minute square
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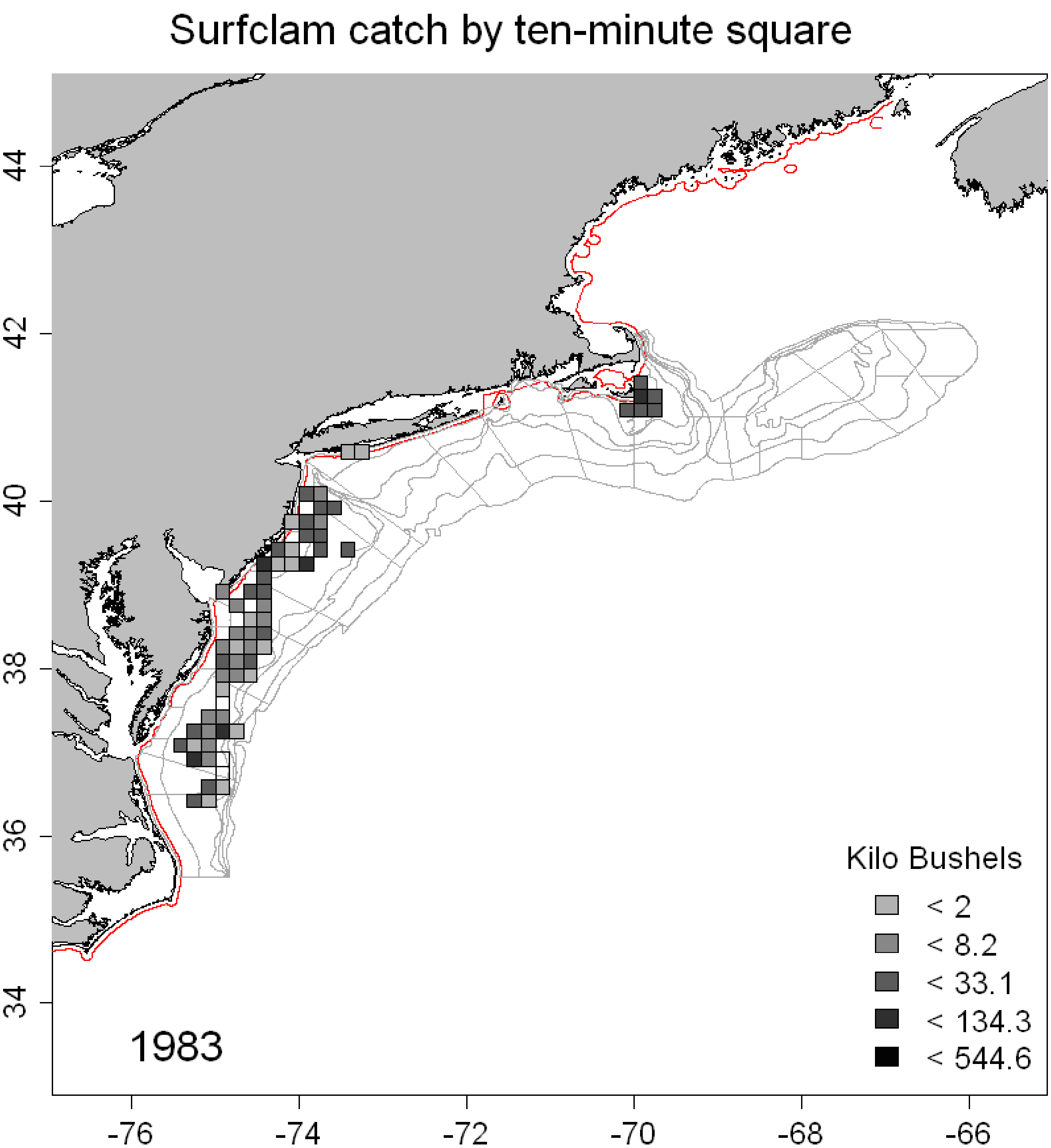
< 544.6



Surfclam catch by ten-minute square
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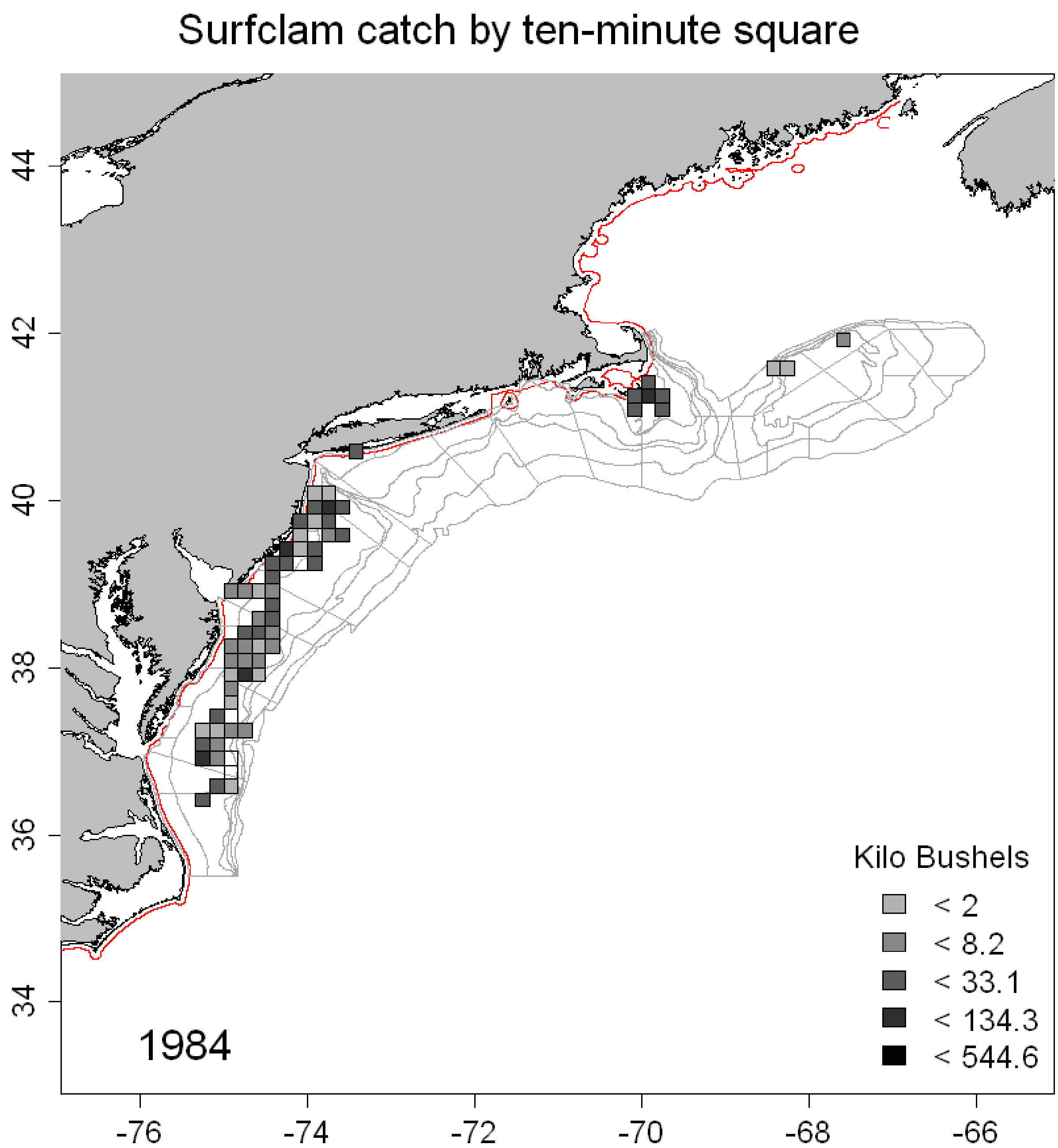
1983



Surfclam catch by ten-minute square
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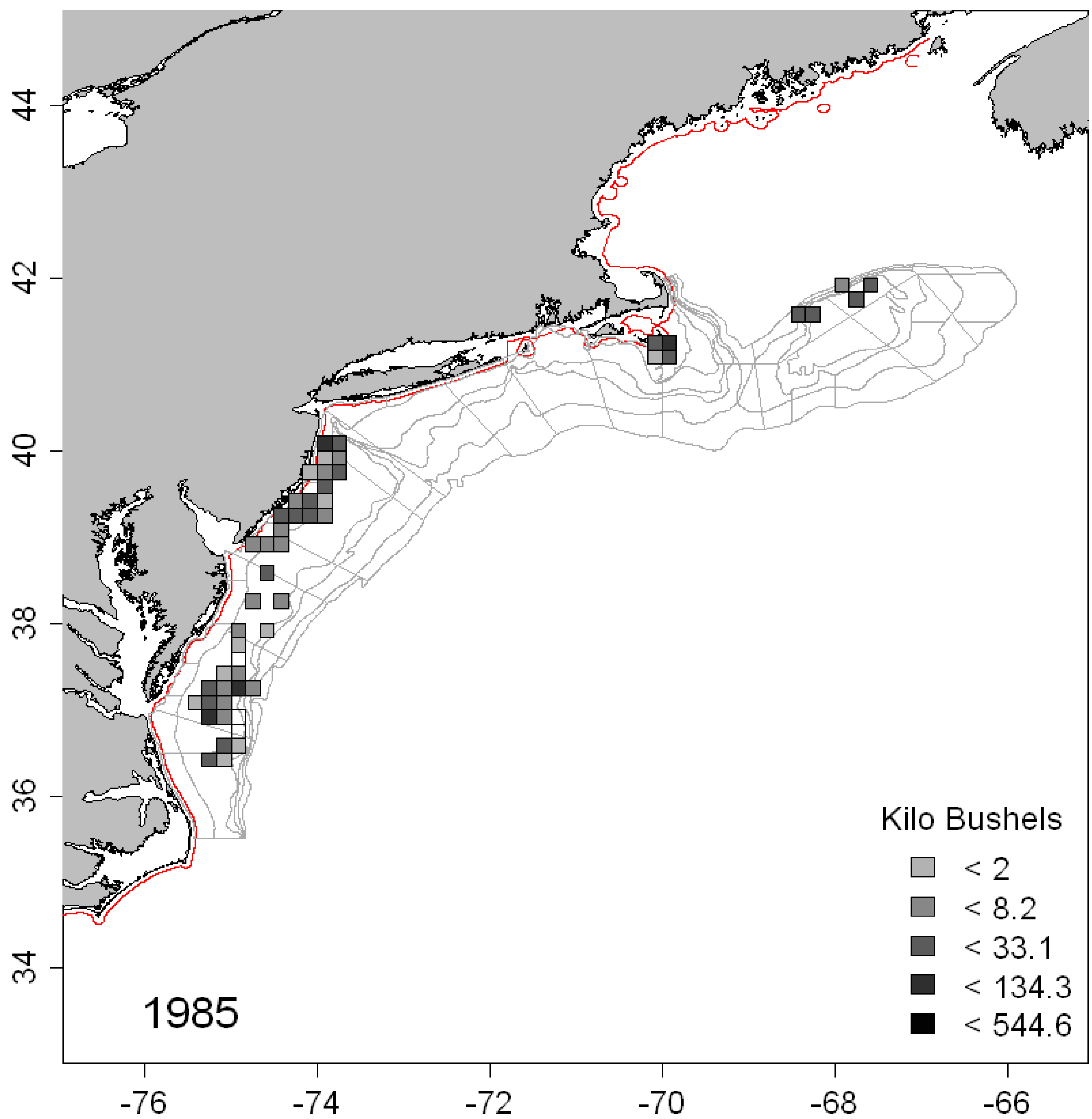
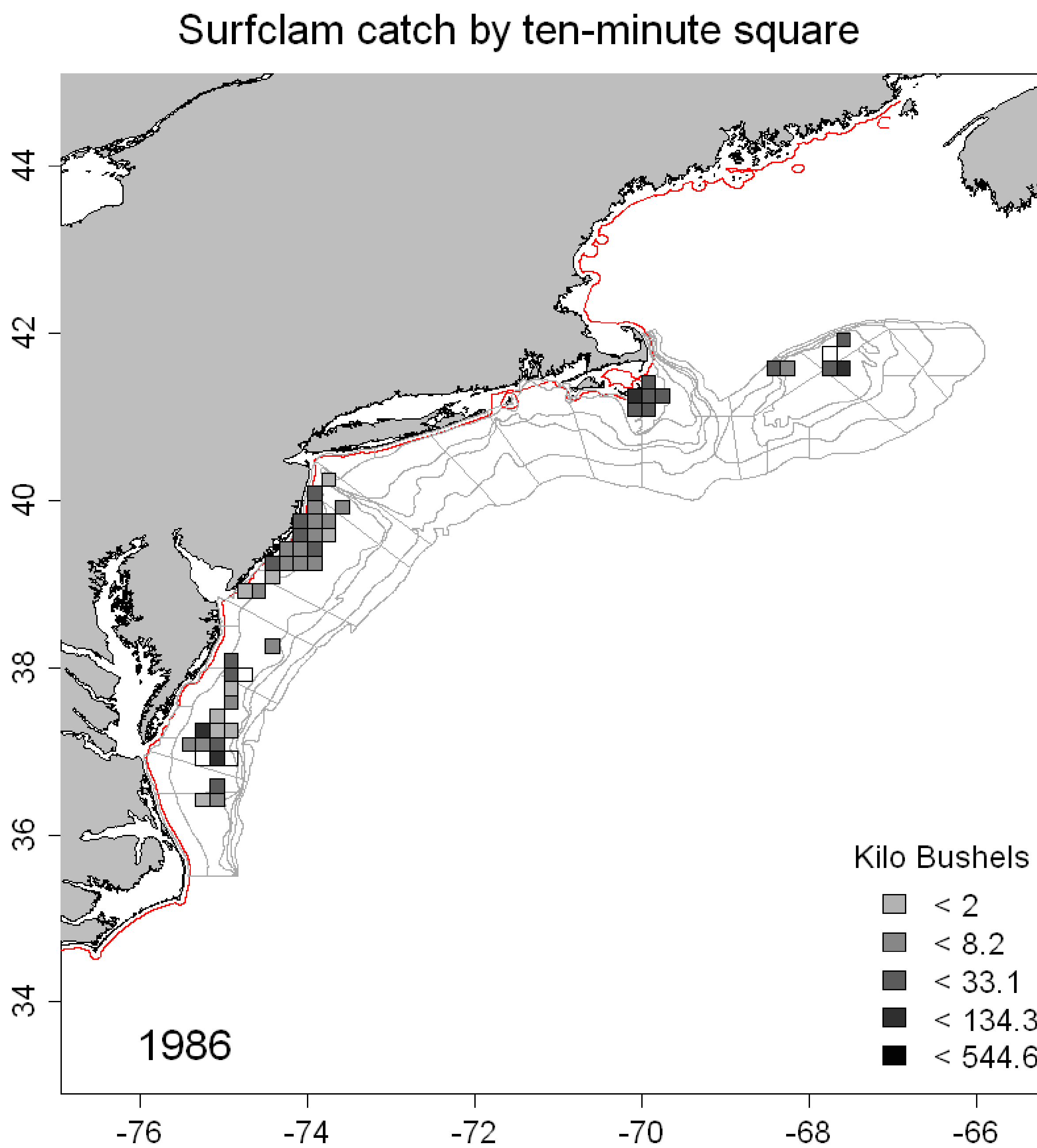
< 544.6
1984

Surfclam catch by ten-minute square




Surfclam catch by ten-minute square
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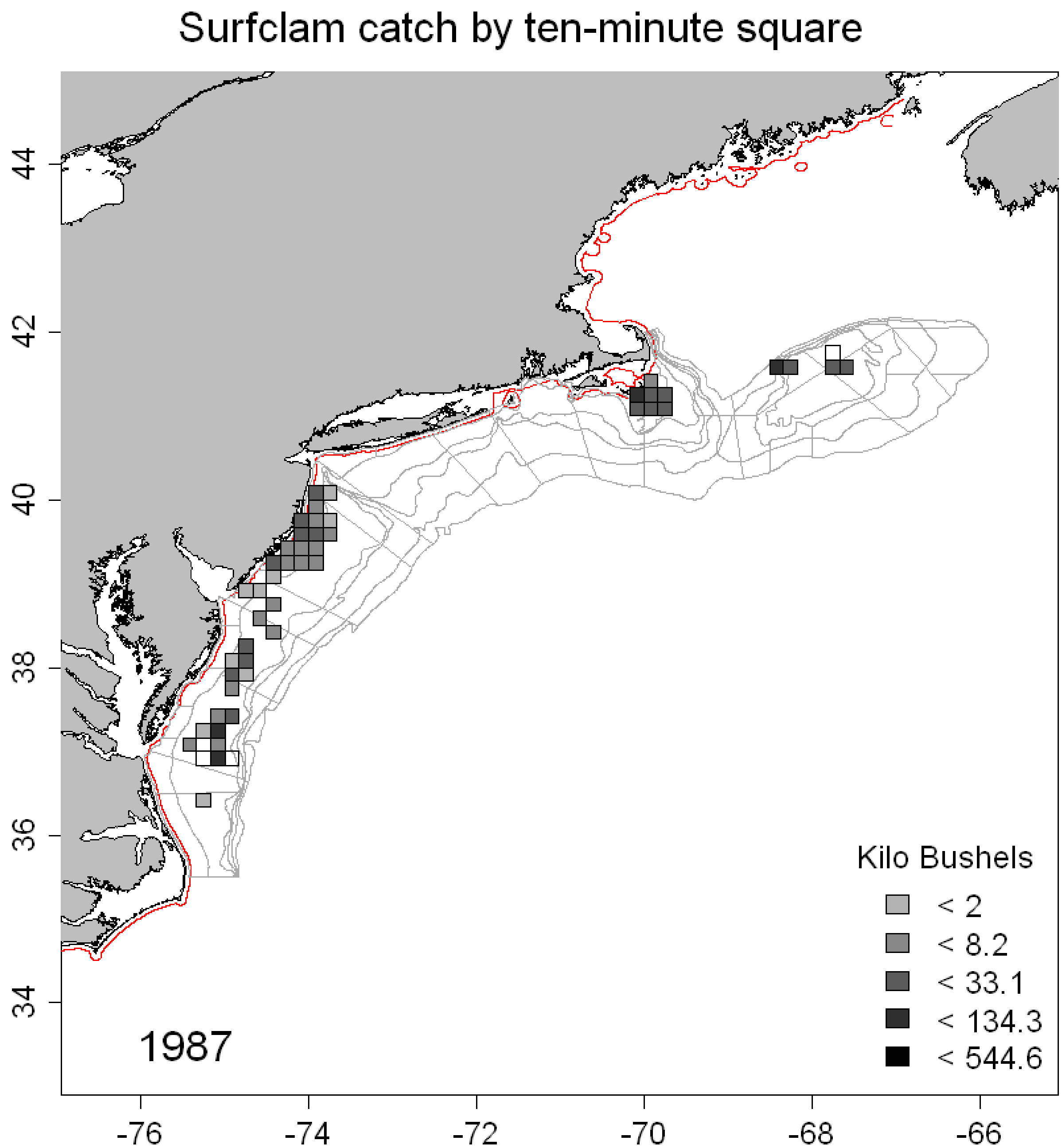
1986


Surfclam catch by ten-minute square
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Kilo Bushels
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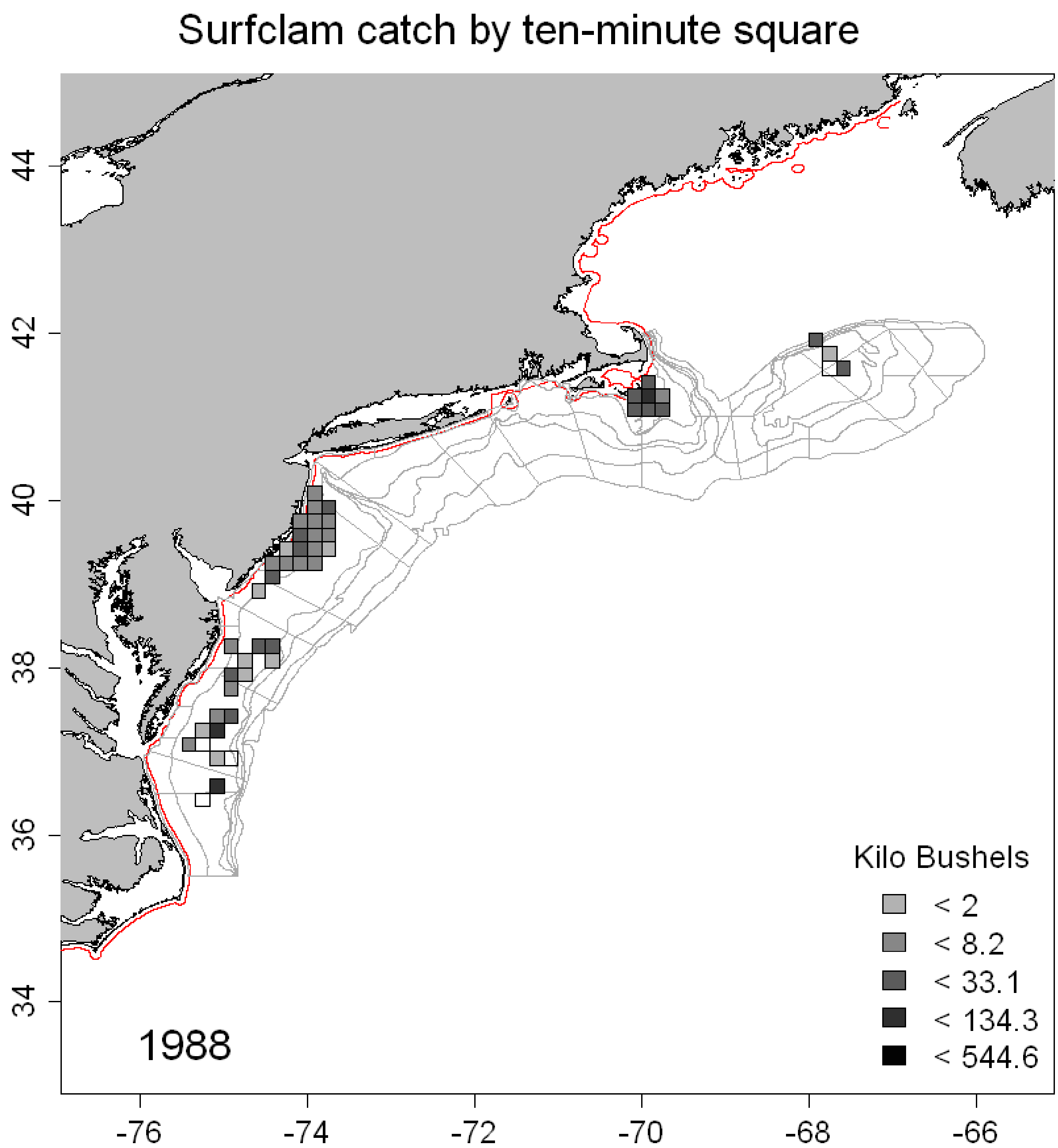
1987


Surfclam catch by ten-minute square
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1988
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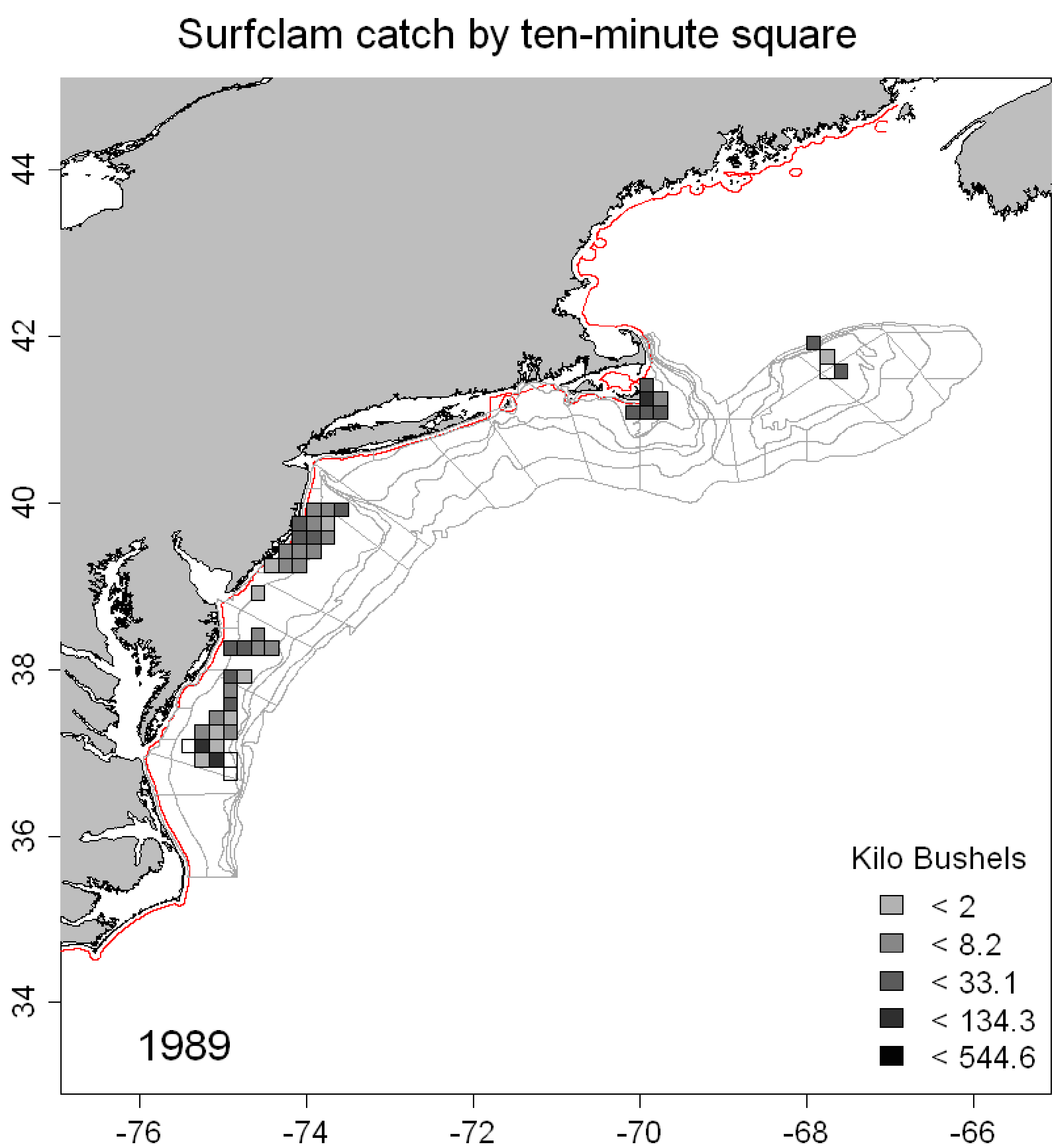
Surfclam catch by ten-minute square
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Kilo Bushels
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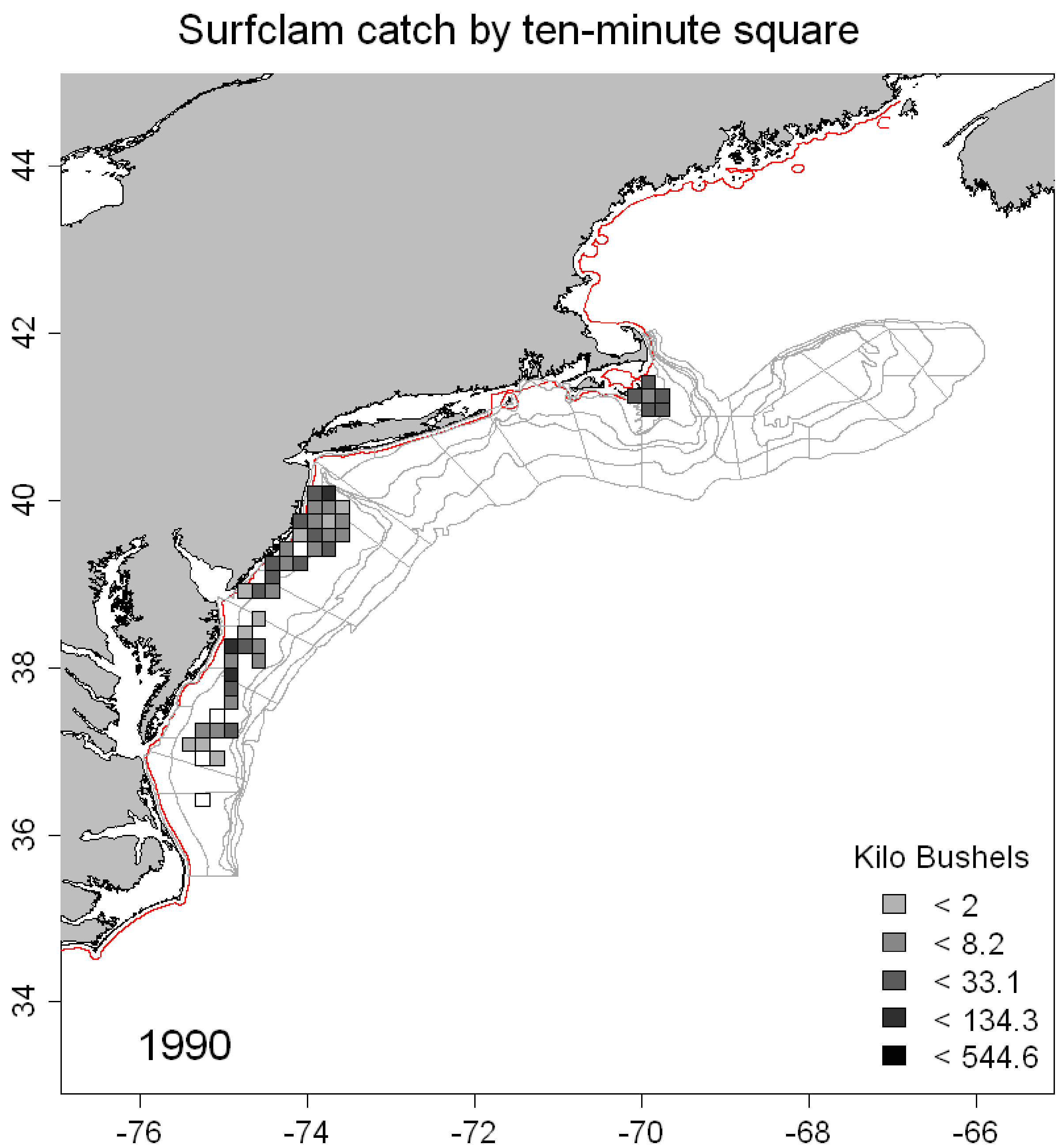
< 134.3
< 544.6
1989


Surfclam catch by ten-minute square
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1990
Kilo Bushels
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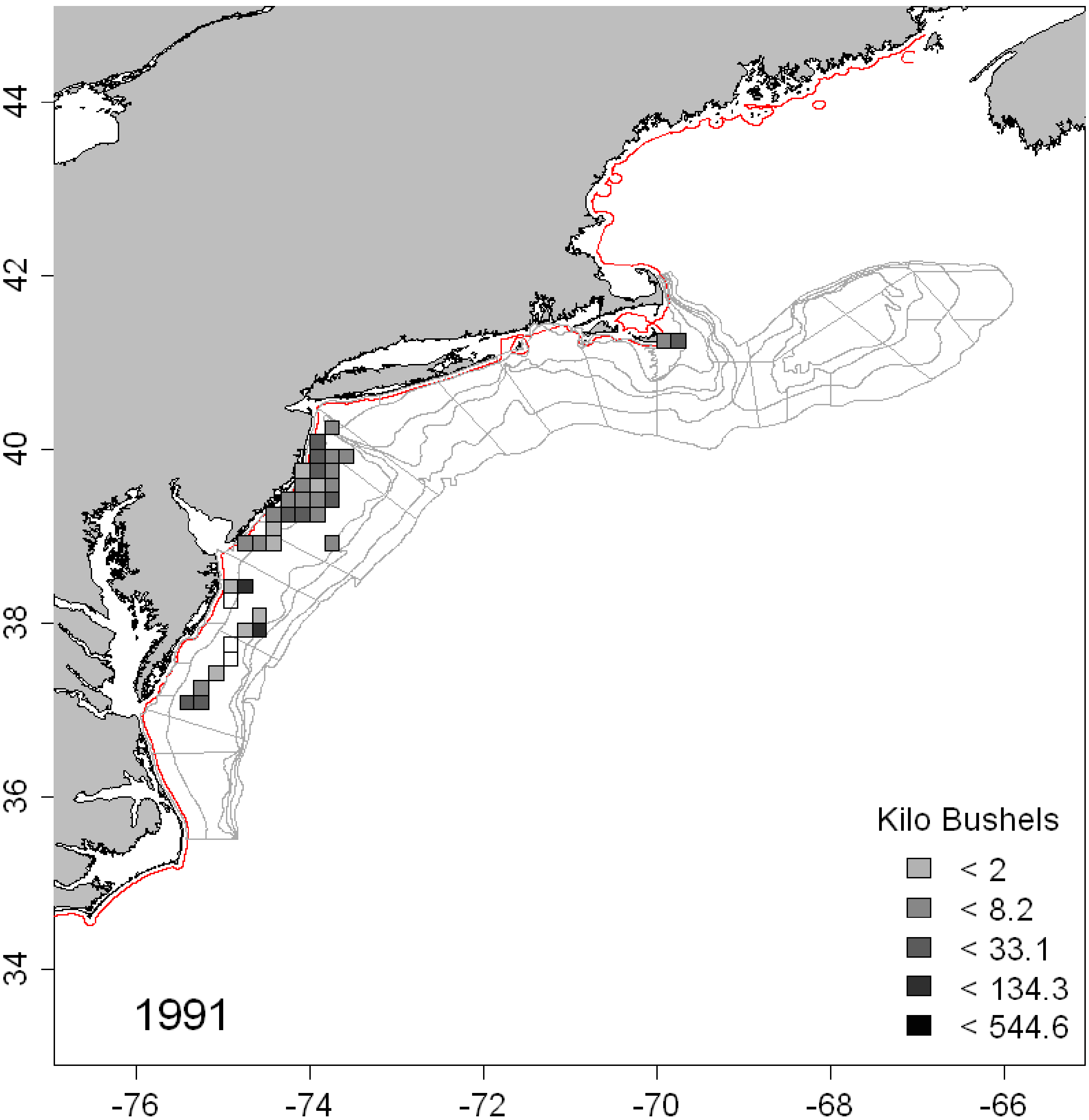
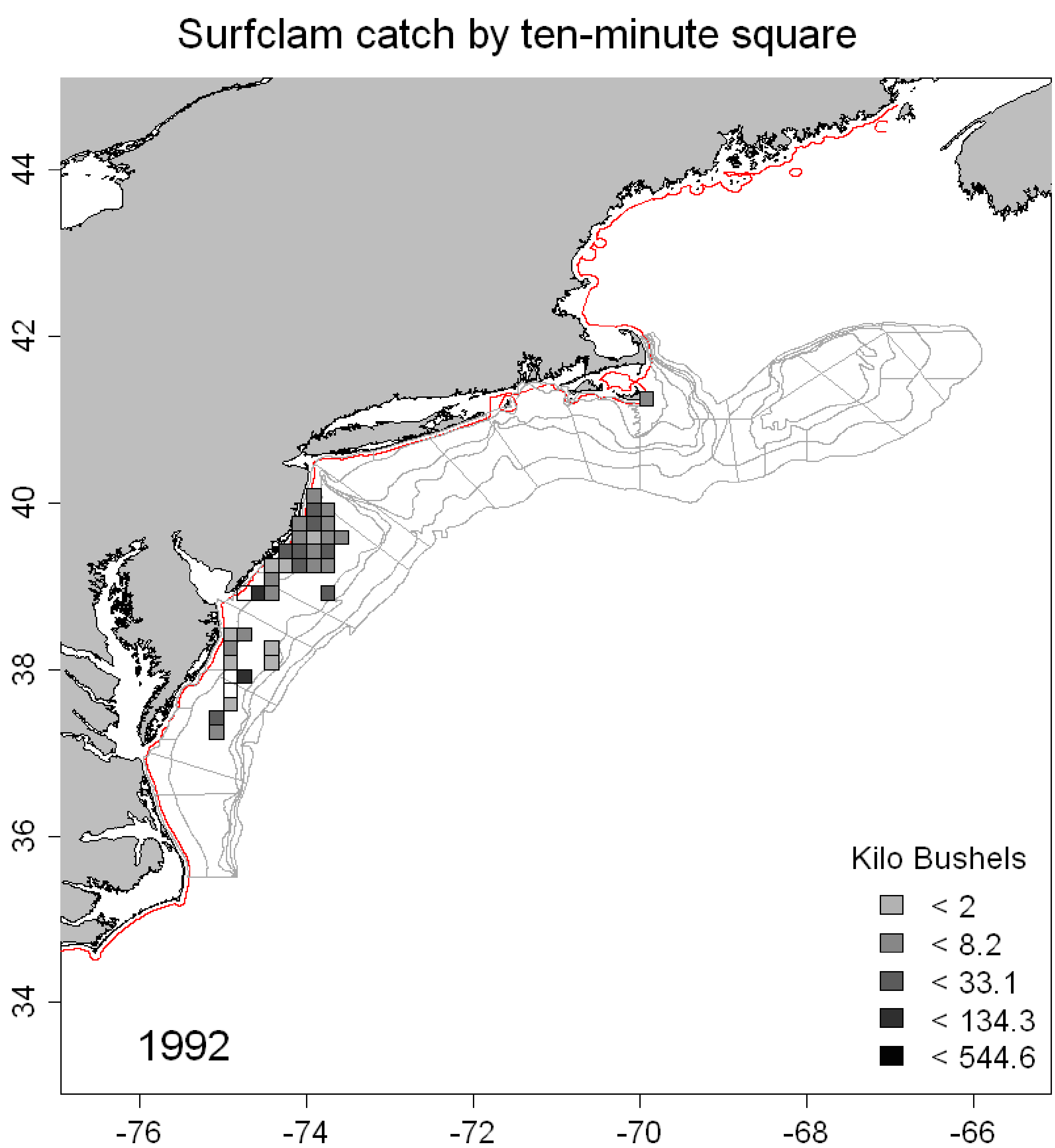
< 134.3
< 544.6

Surfclam catch by ten-minute square




Surfclam catch by ten-minute square
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-76
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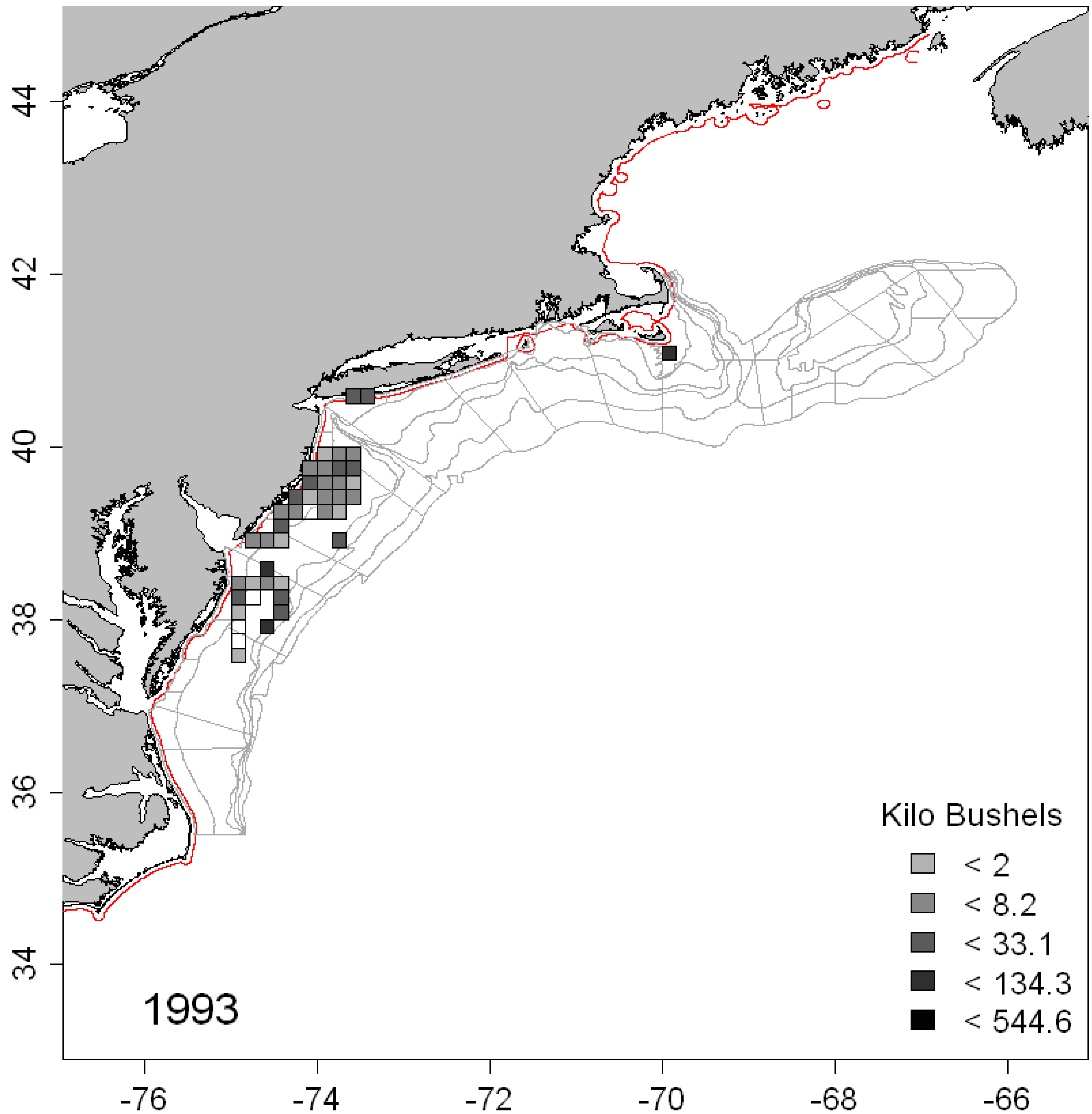
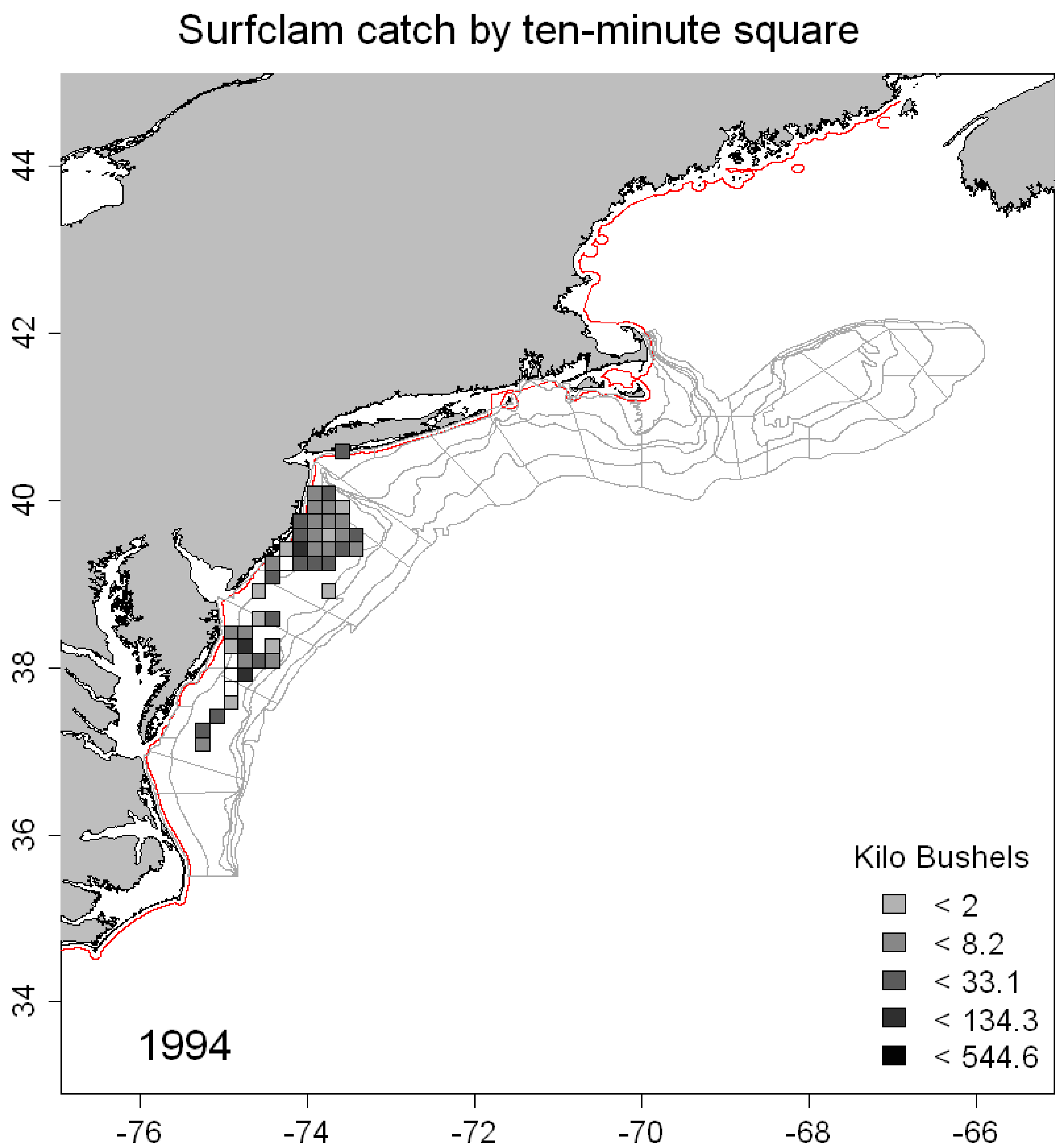
-66
Kilo Bushels
< 2
< 8.2
< 33.1
< 134.3
< 544.6
1992

Surfclam catch by ten-minute square




Surfclam catch by ten-minute square
44
42
40
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36
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1994
Kilo Bushels
< 2
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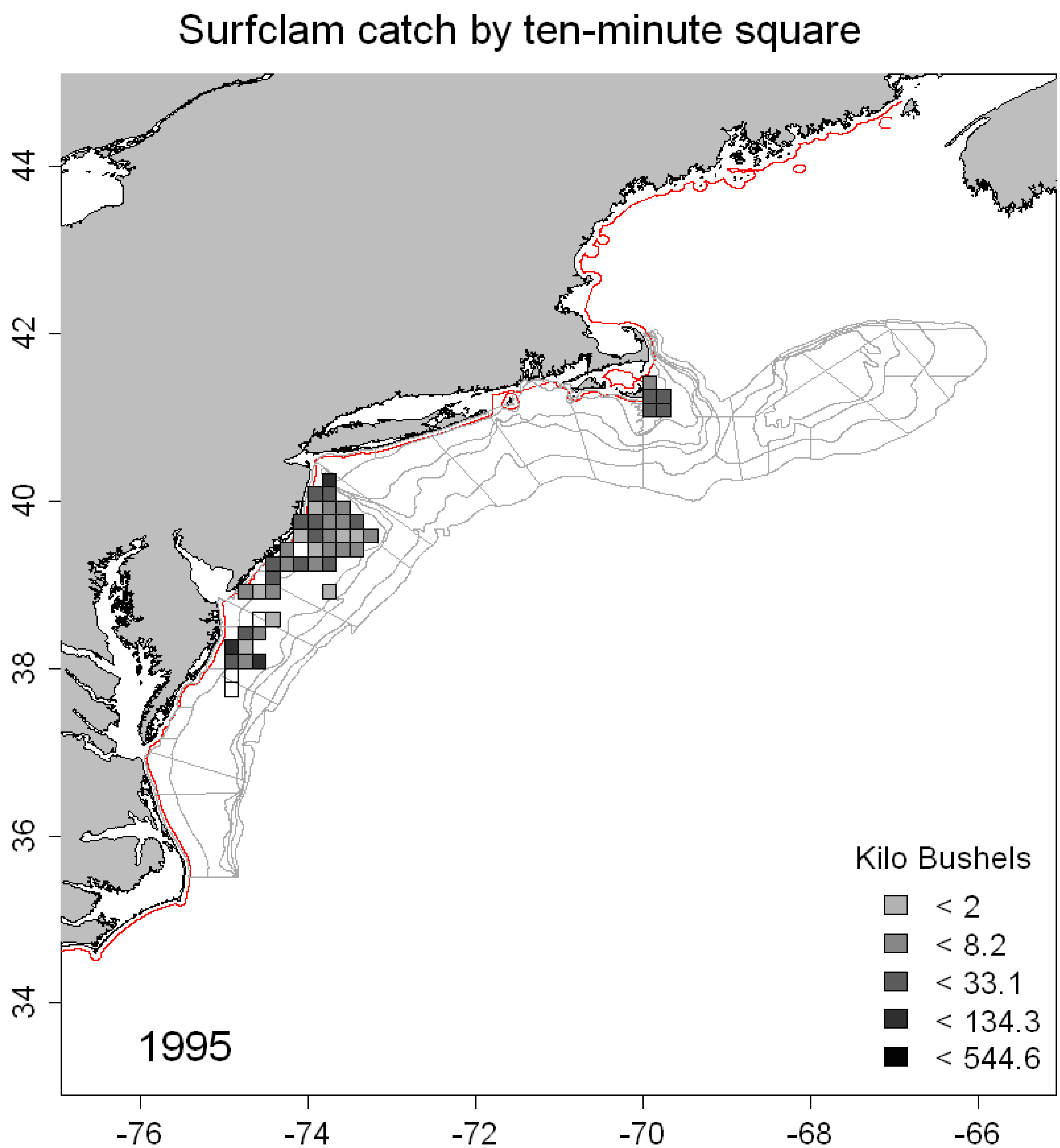

Surfclam catch by ten-minute square
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40
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36
34
-76
-74
-72
-70
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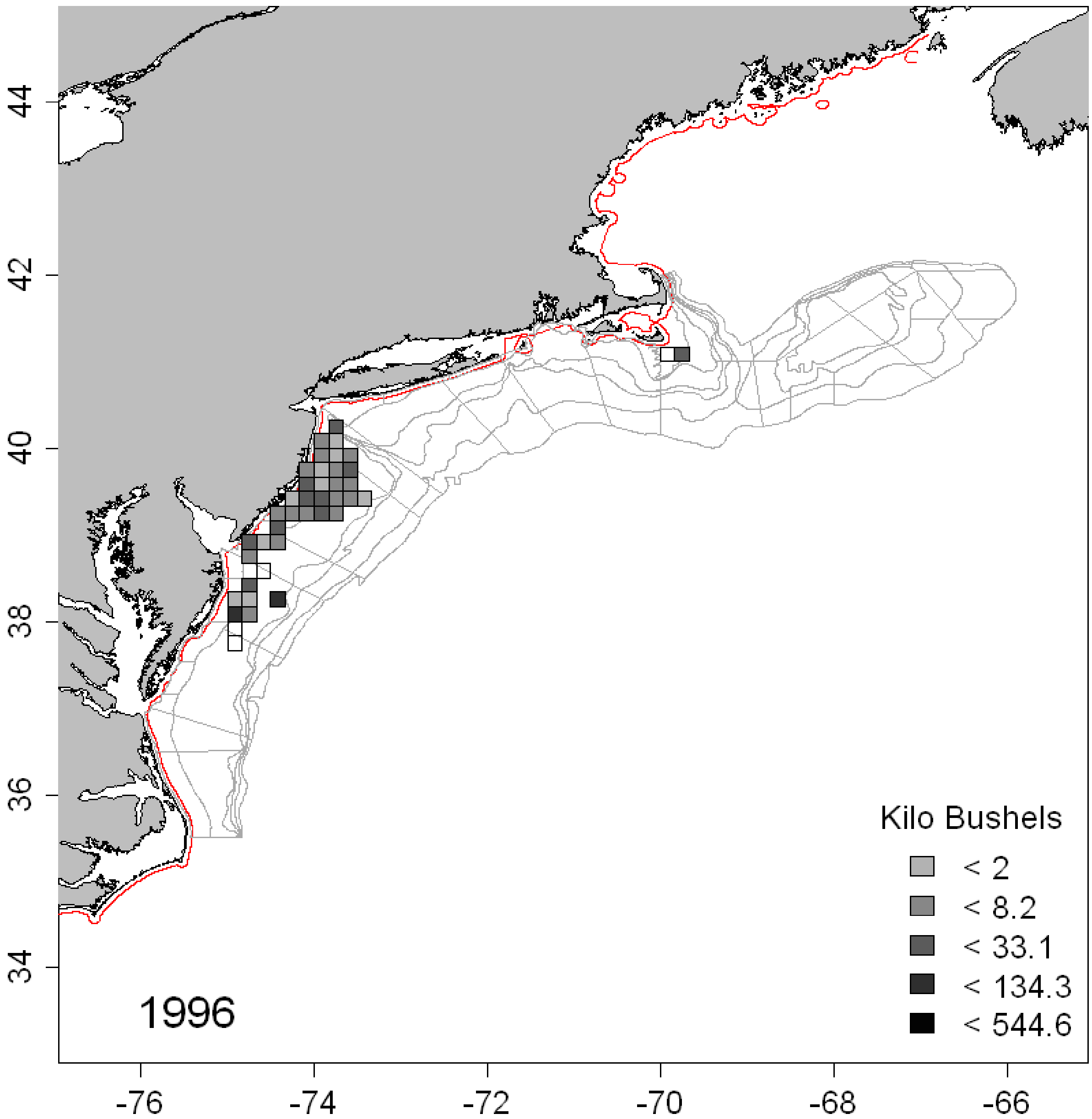
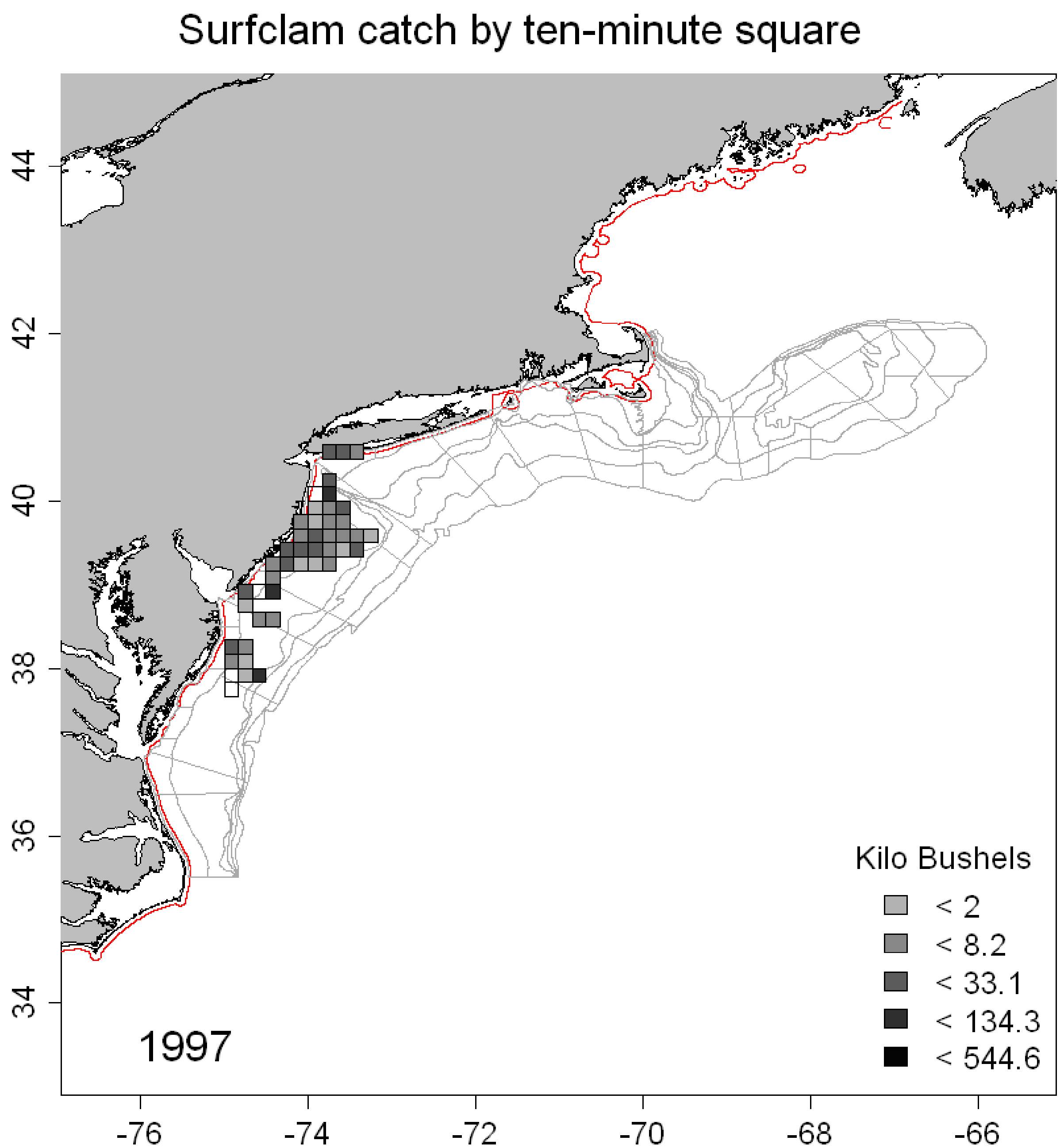
-66
Kilo Bushels
< 2
< 8.2
< 33.1
< 134.3
< 544.6
1995

Surfclam catch by ten-minute square





Surfclam catch by ten-minute square
44
42
40
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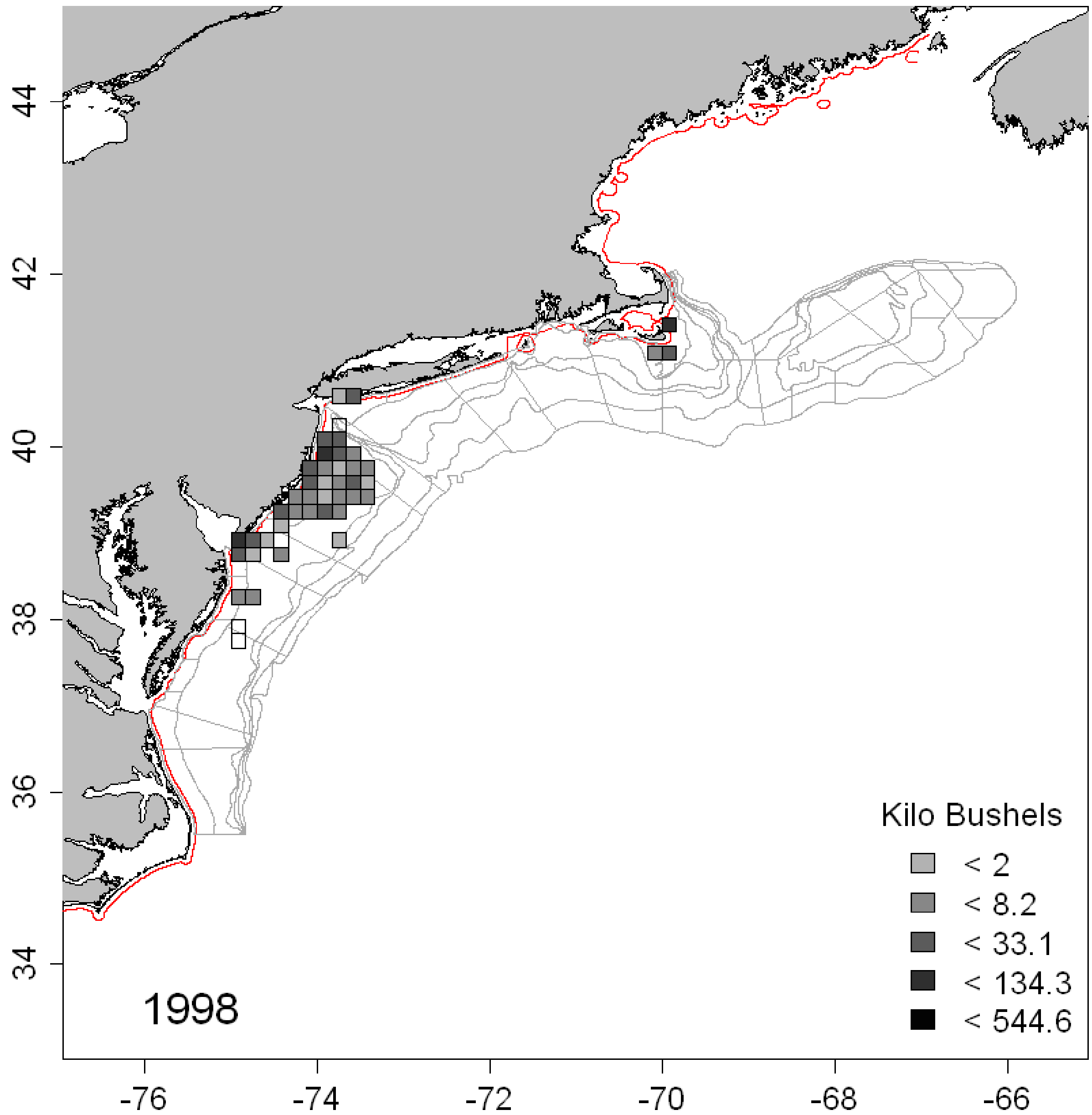
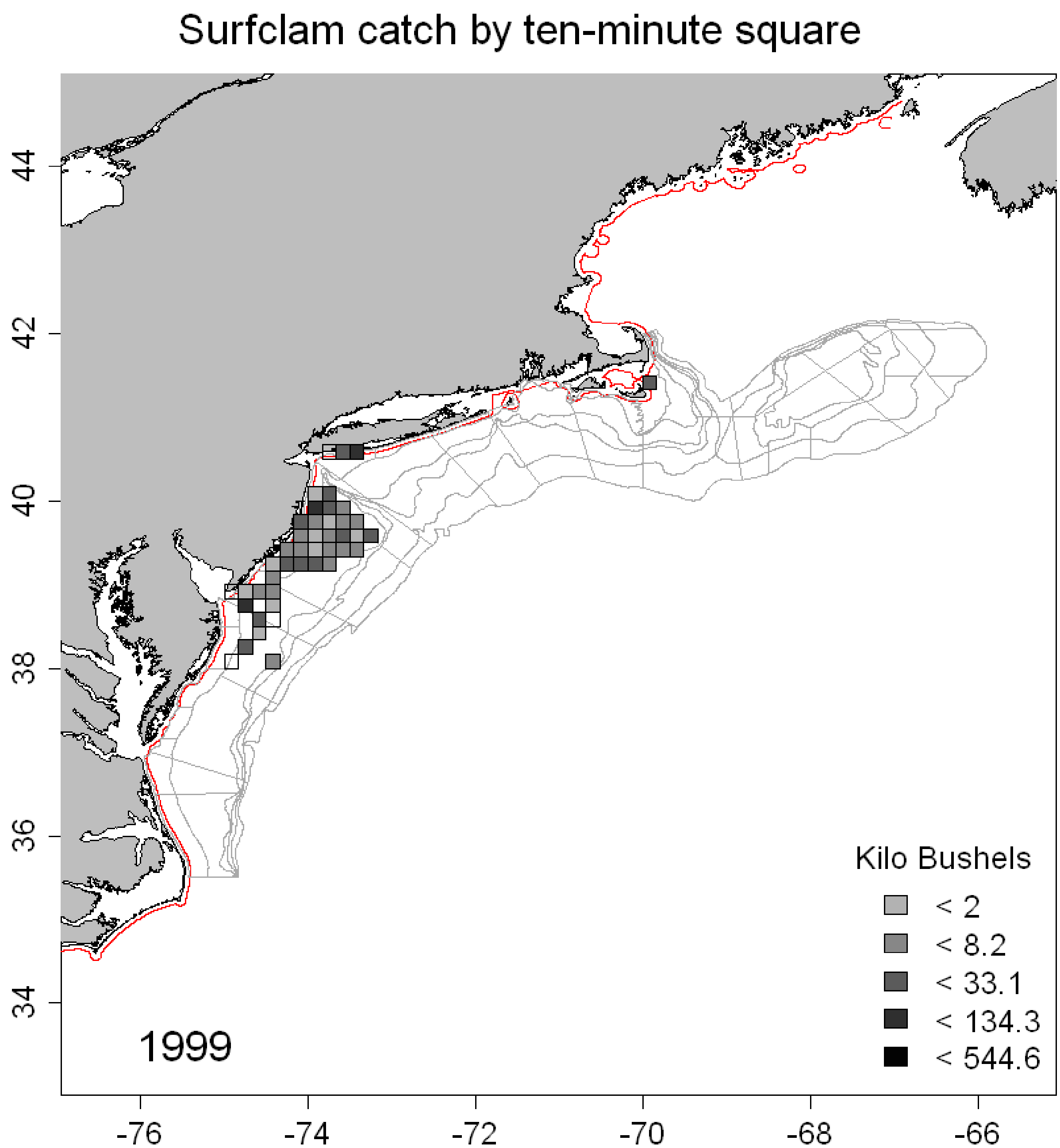
36
34
1997
Kilo Bushels
< 2
< 8.2
< 33.1
< 134.3
< 544.6
-76
-74
-72
-70
-68
-66

Surfclam catch by ten-minute square




Surfclam catch by ten-minute square
44
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Kilo Bushels
< 2
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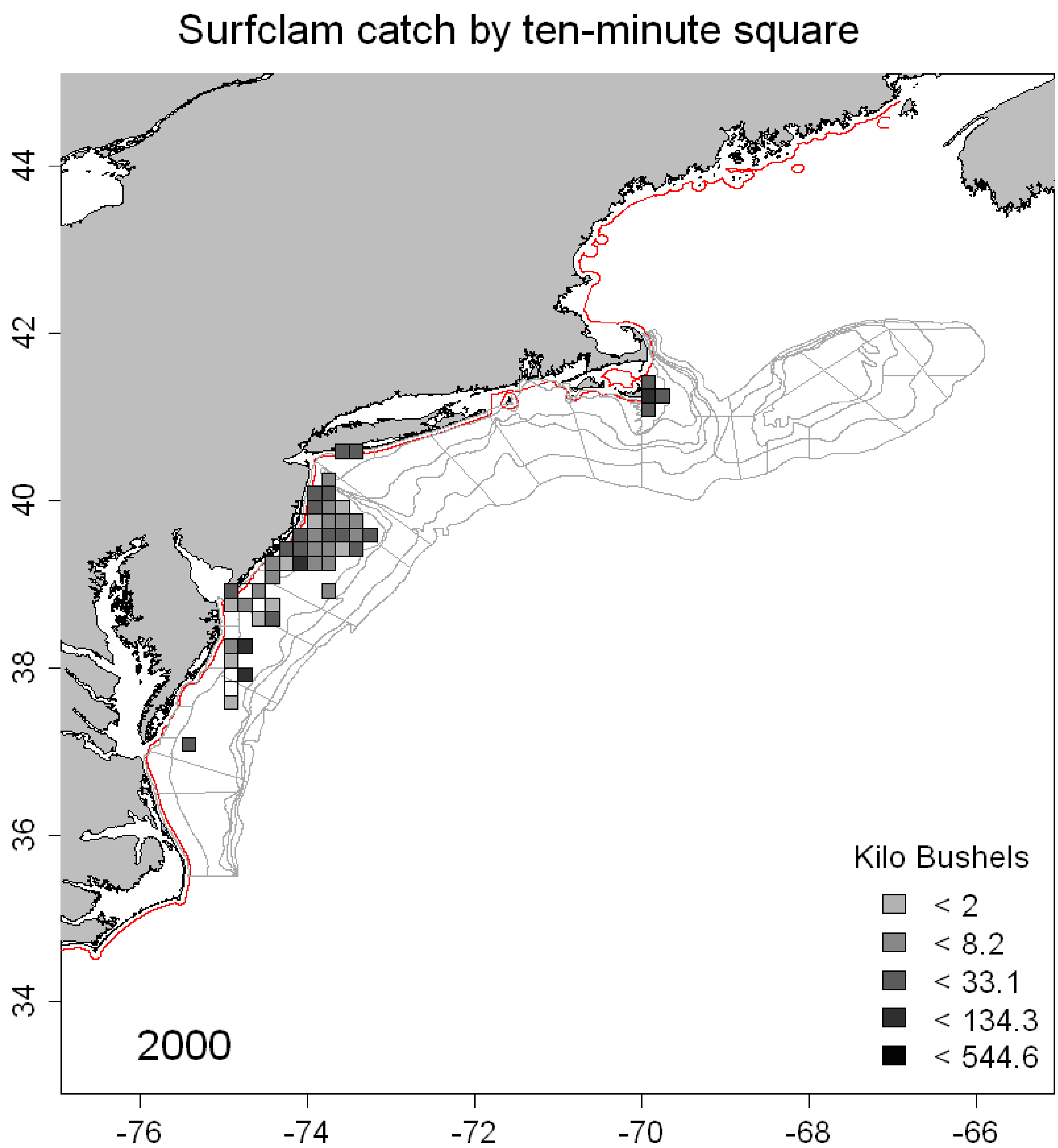
Surfclam catch by ten-minute square
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Kilo Bushels
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< 33.1
< 134.3
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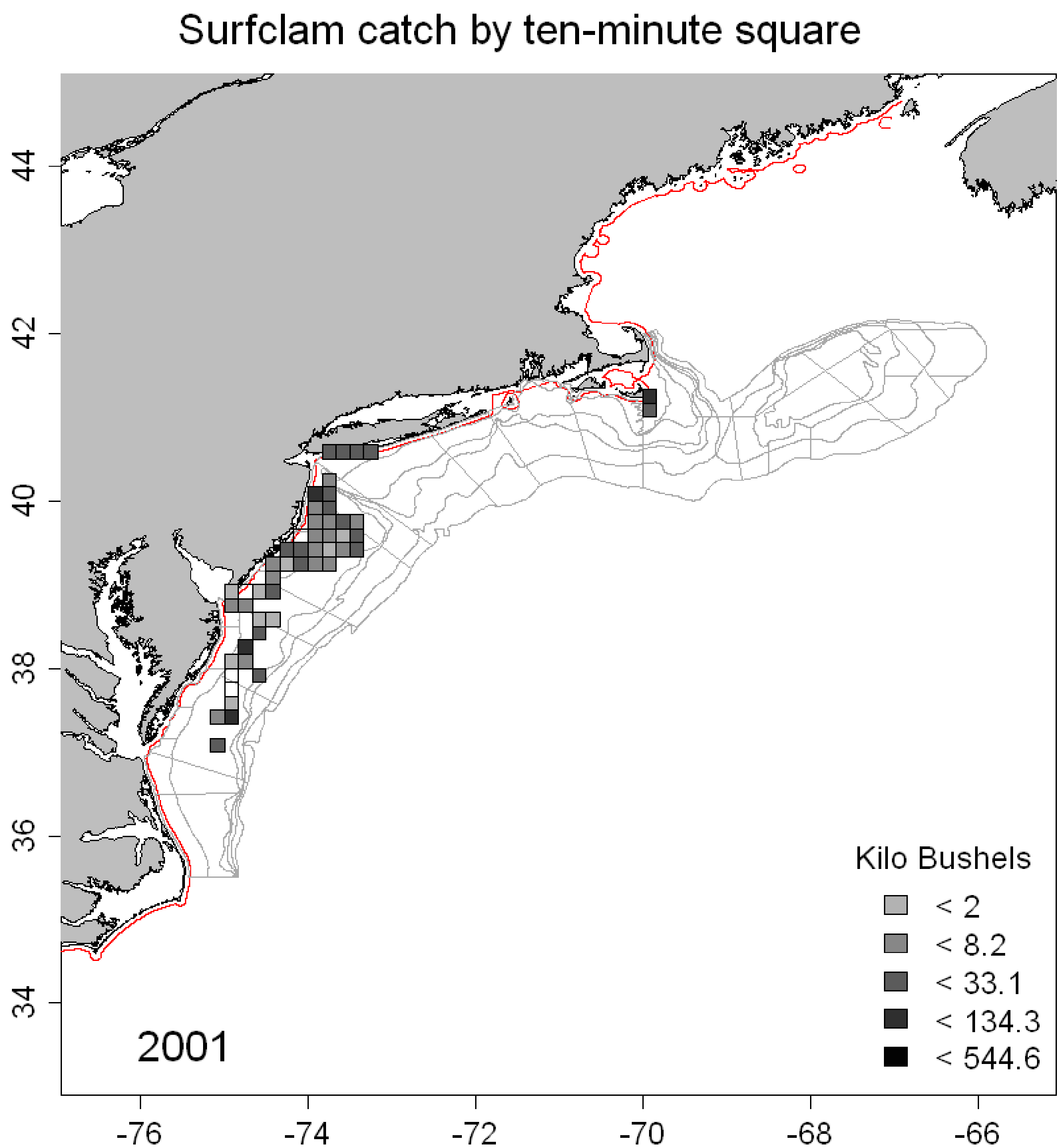
Surfclam catch by ten-minute square
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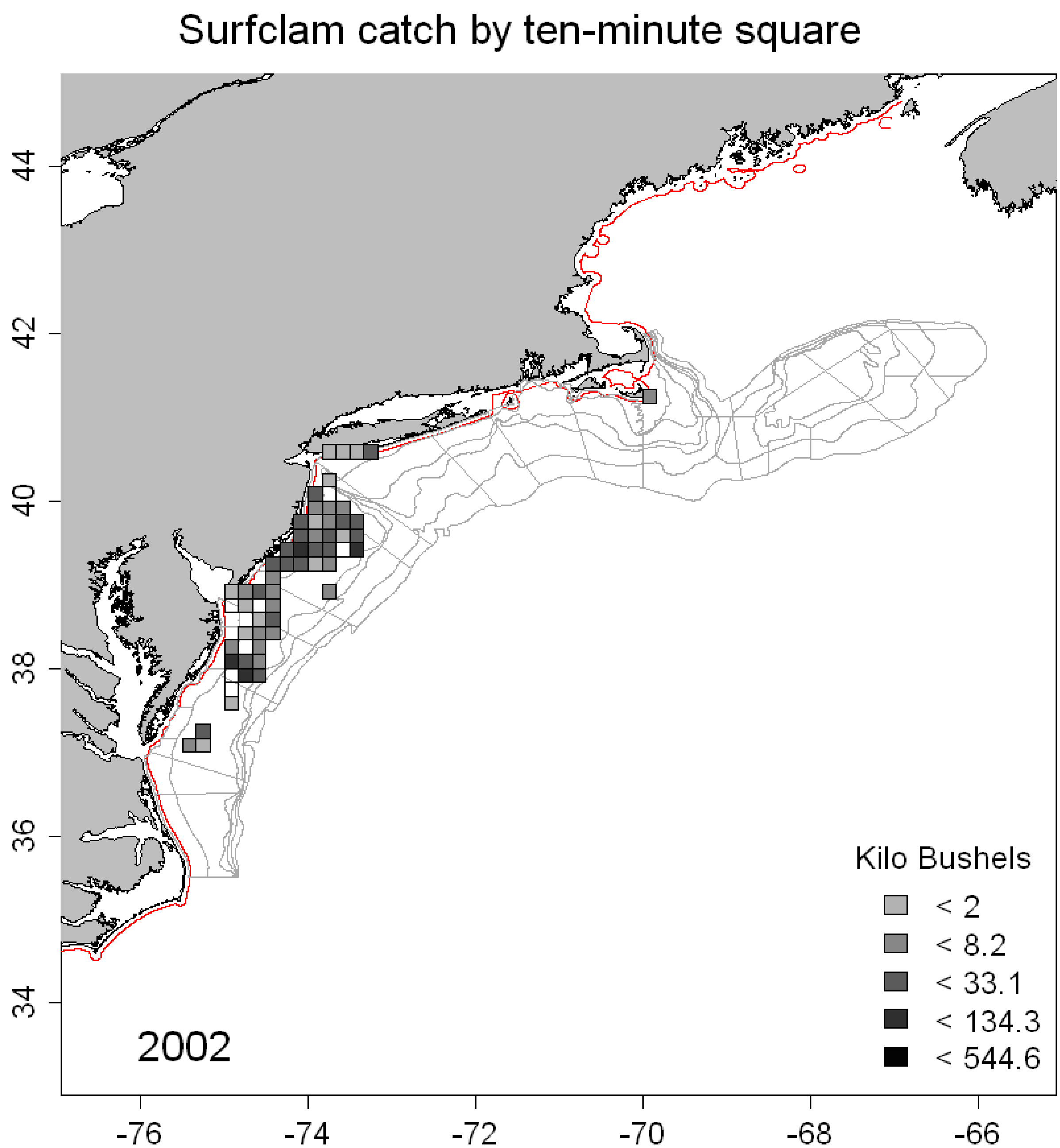

Surfclam catch by ten-minute square
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2002
Kilo Bushels
< 2
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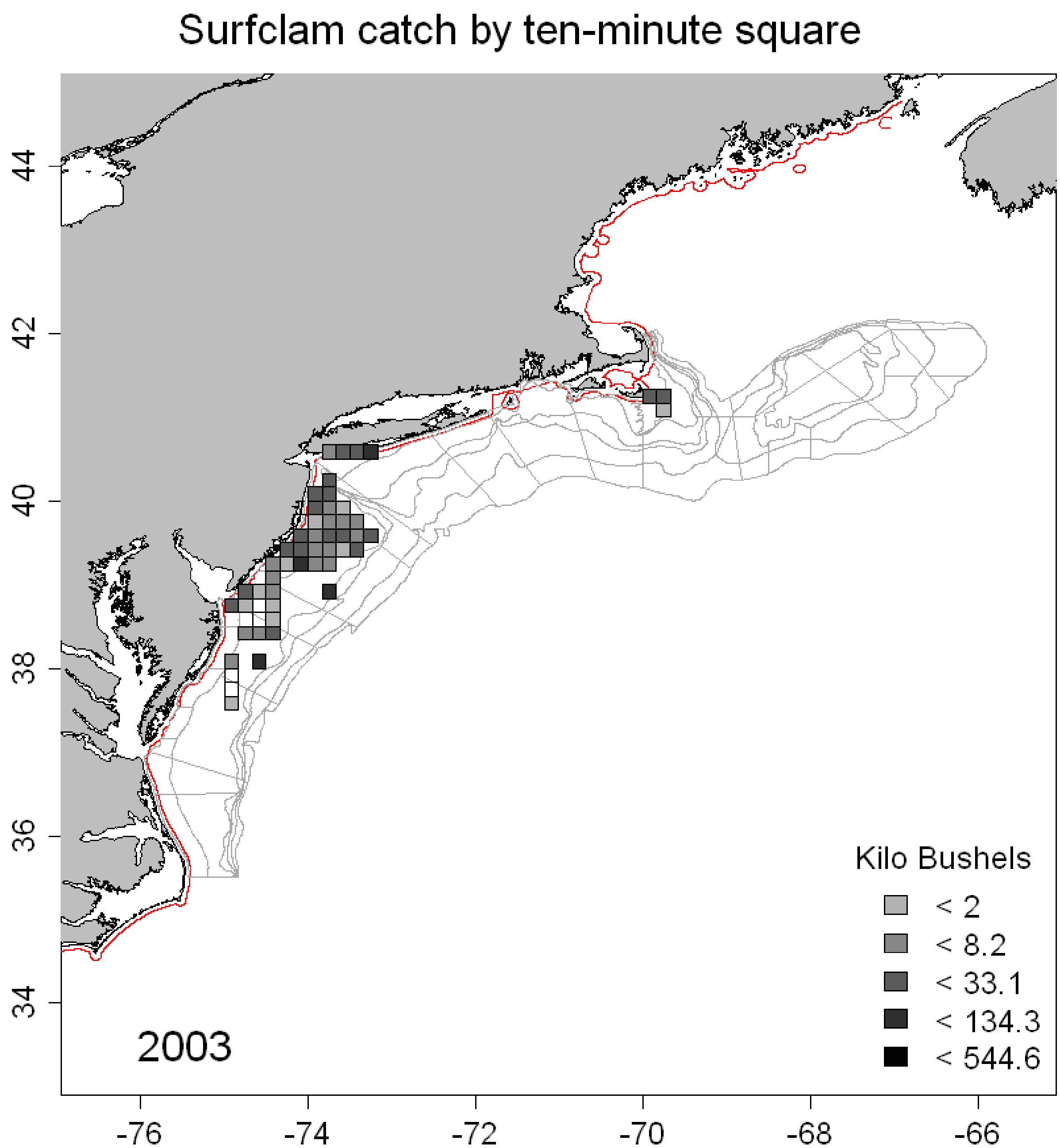
< 134.3
< 544.6


Surfclam catch by ten-minute square
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Kilo Bushels
< 2
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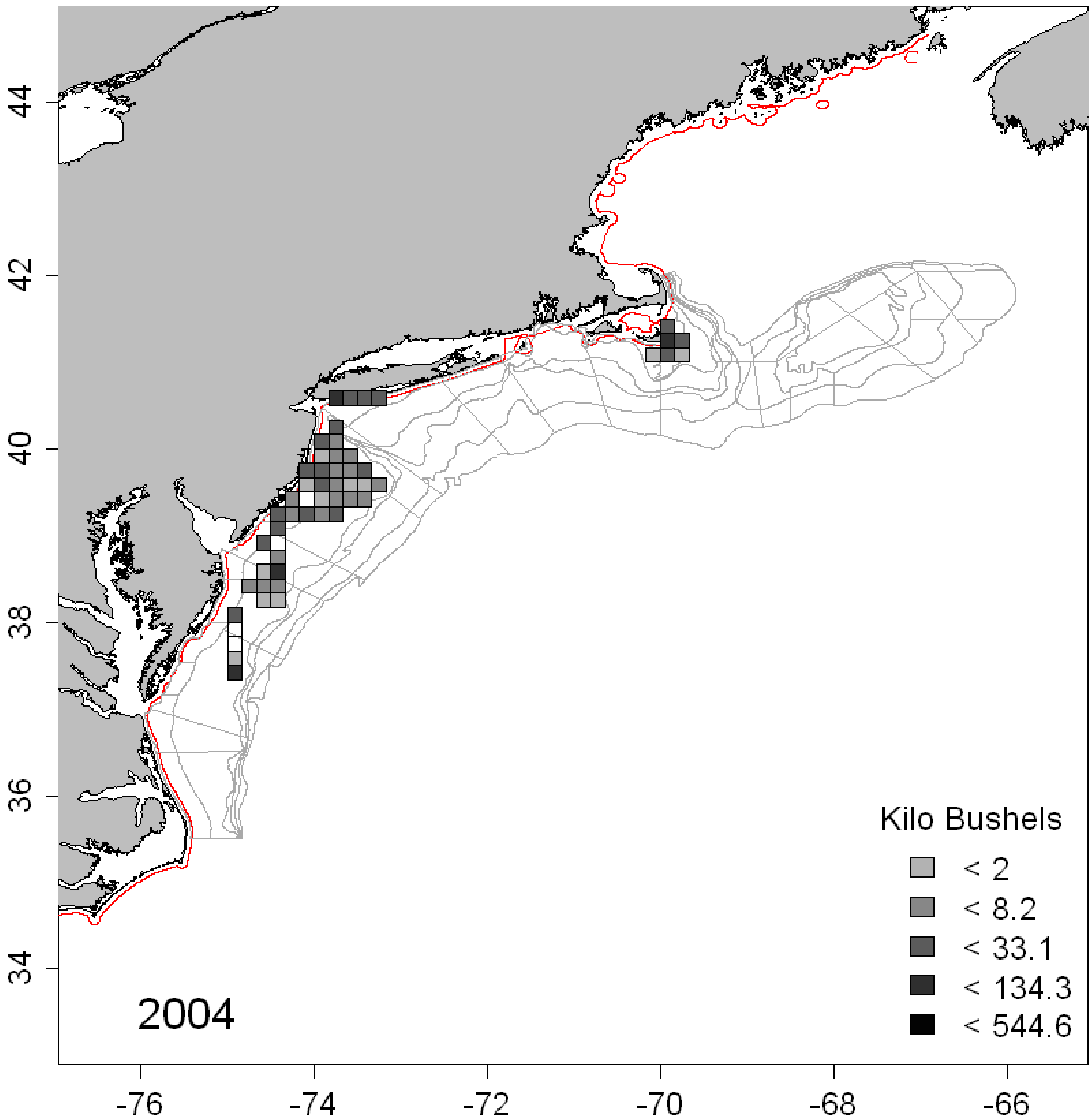
< 33.1
< 134.3
< 544.6
2003

Surfclam catch by ten-minute square



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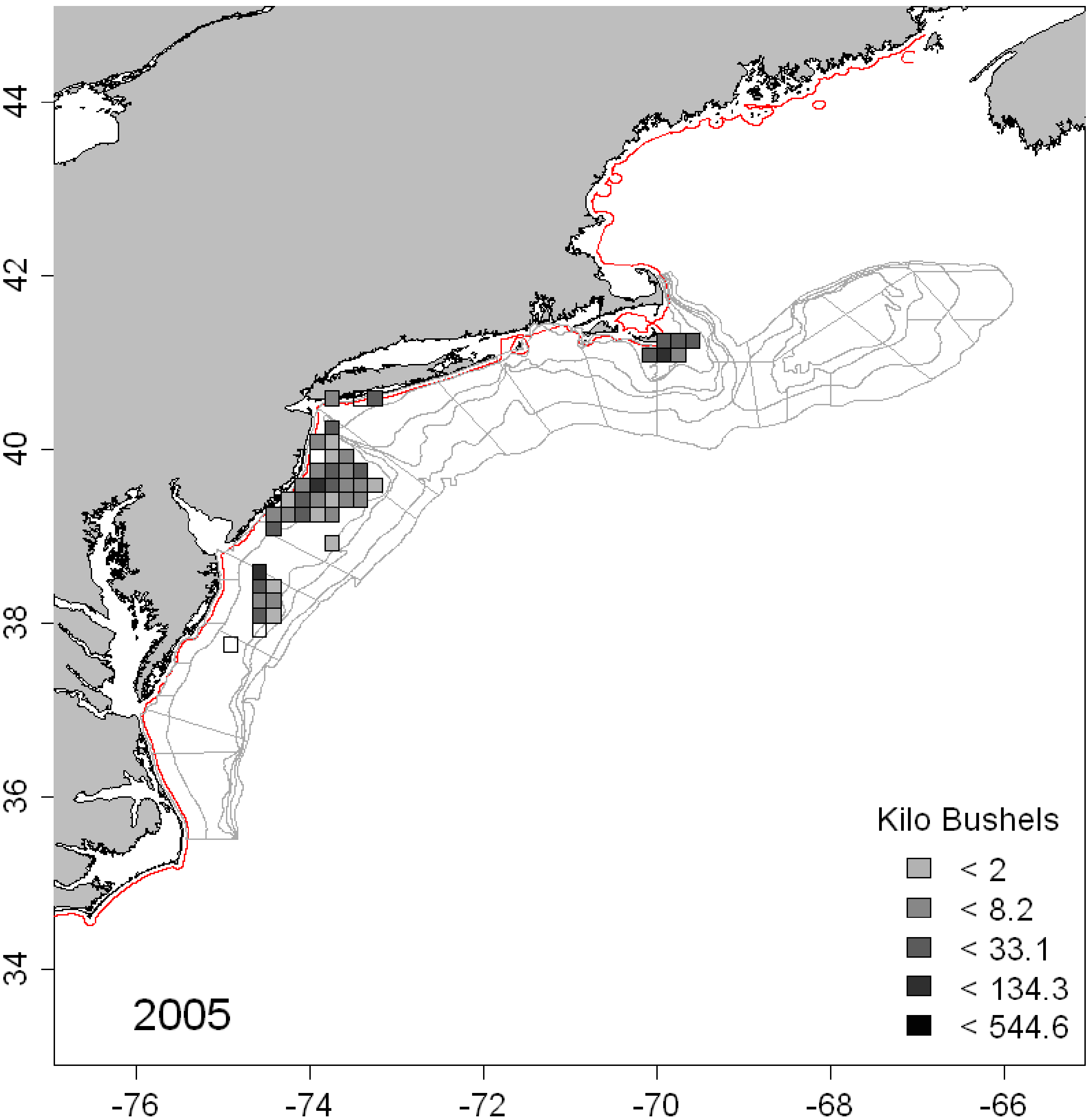

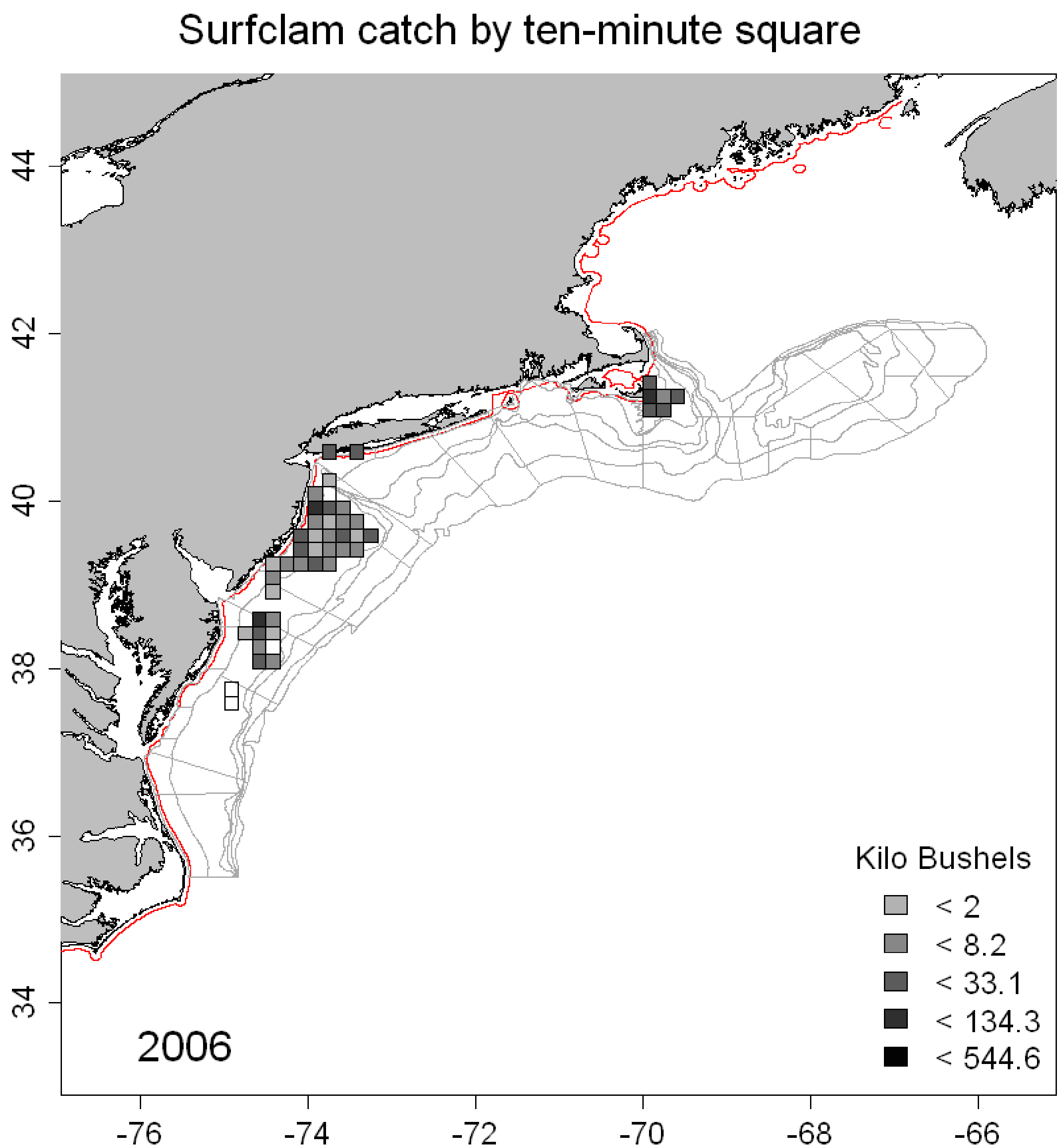
Surfclam catch by ten-minute square
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Kilo Bushels
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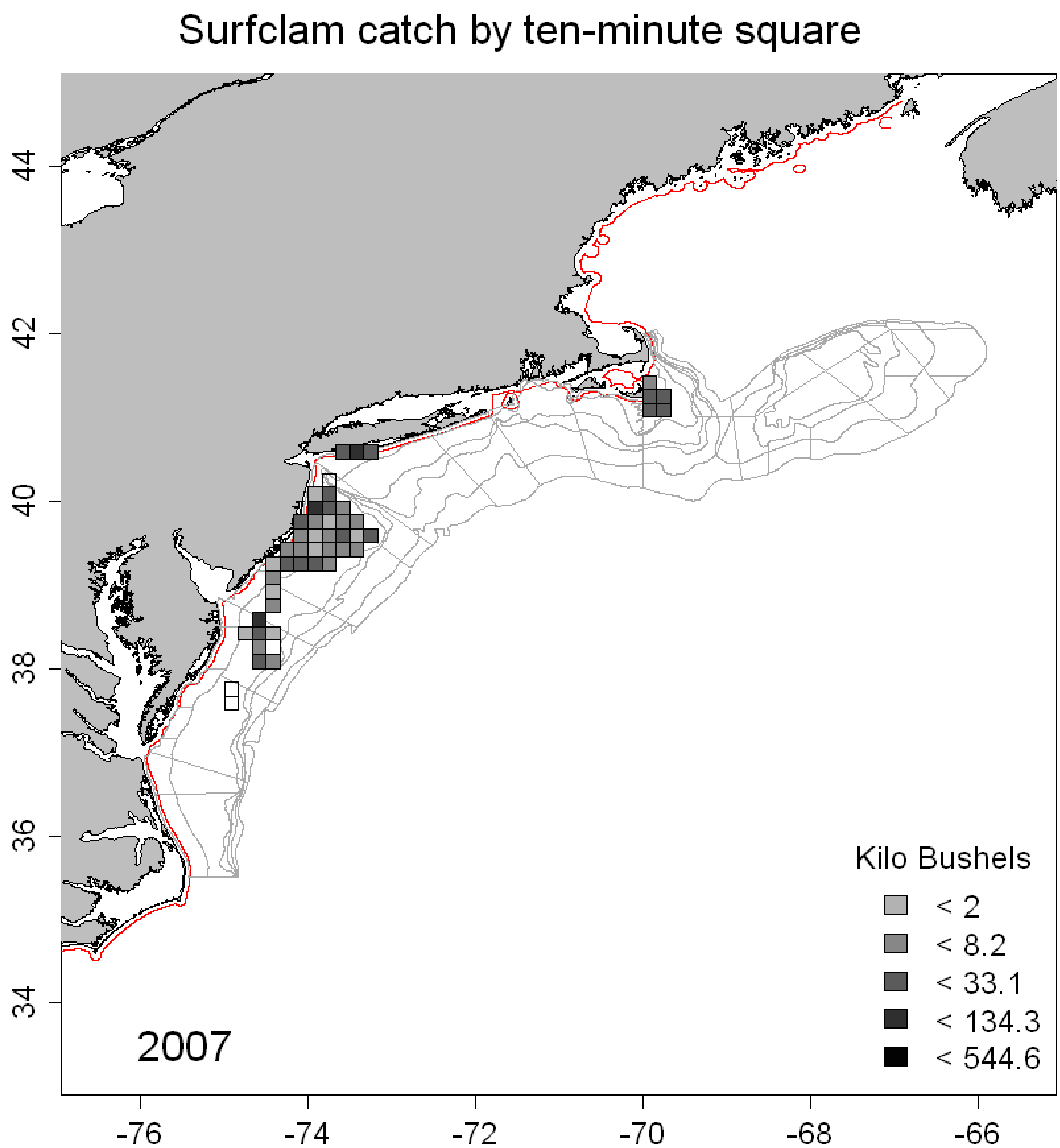
< 134.3
< 544.6
2006



Surfclam catch by ten-minute square
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2007
Kilo Bushels
< 2
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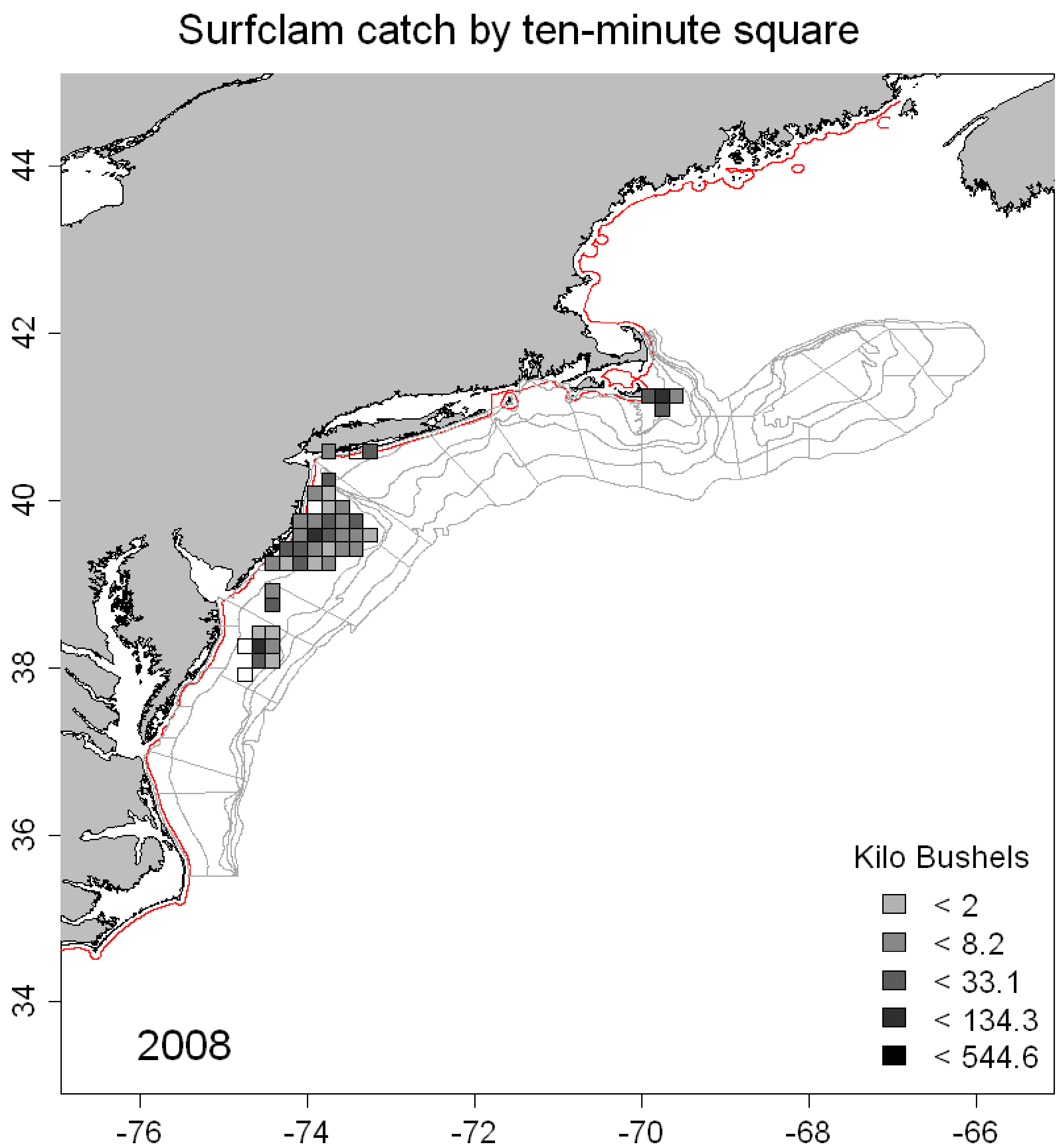
< 544.6


Surfclam catch by ten-minute square
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Kilo Bushels
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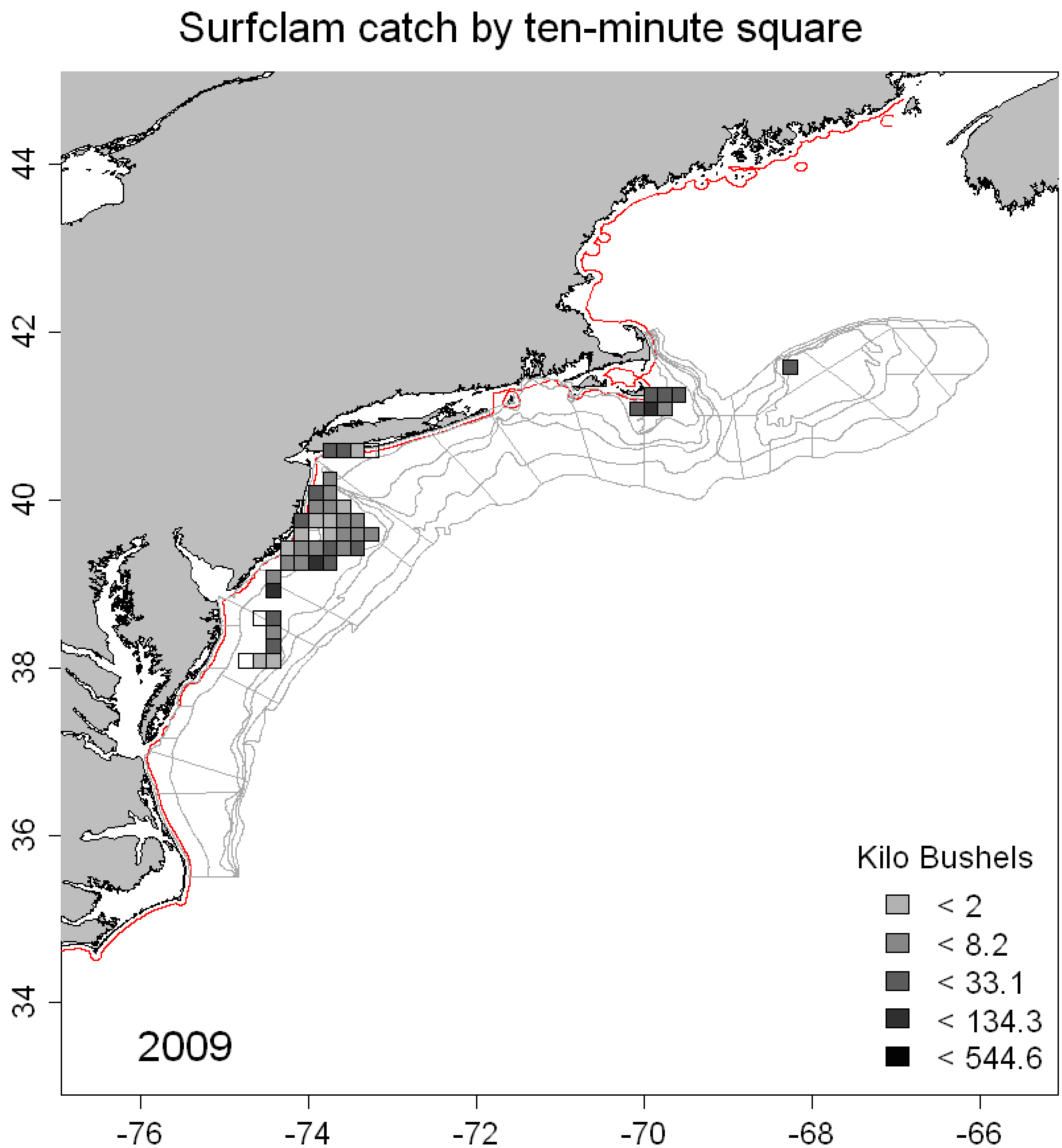
< 134.3
< 544.6
2008



Surfclam catch by ten-minute square
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-76
-74
-72
-70
-68
-66
2009
Kilo Bushels
< 2
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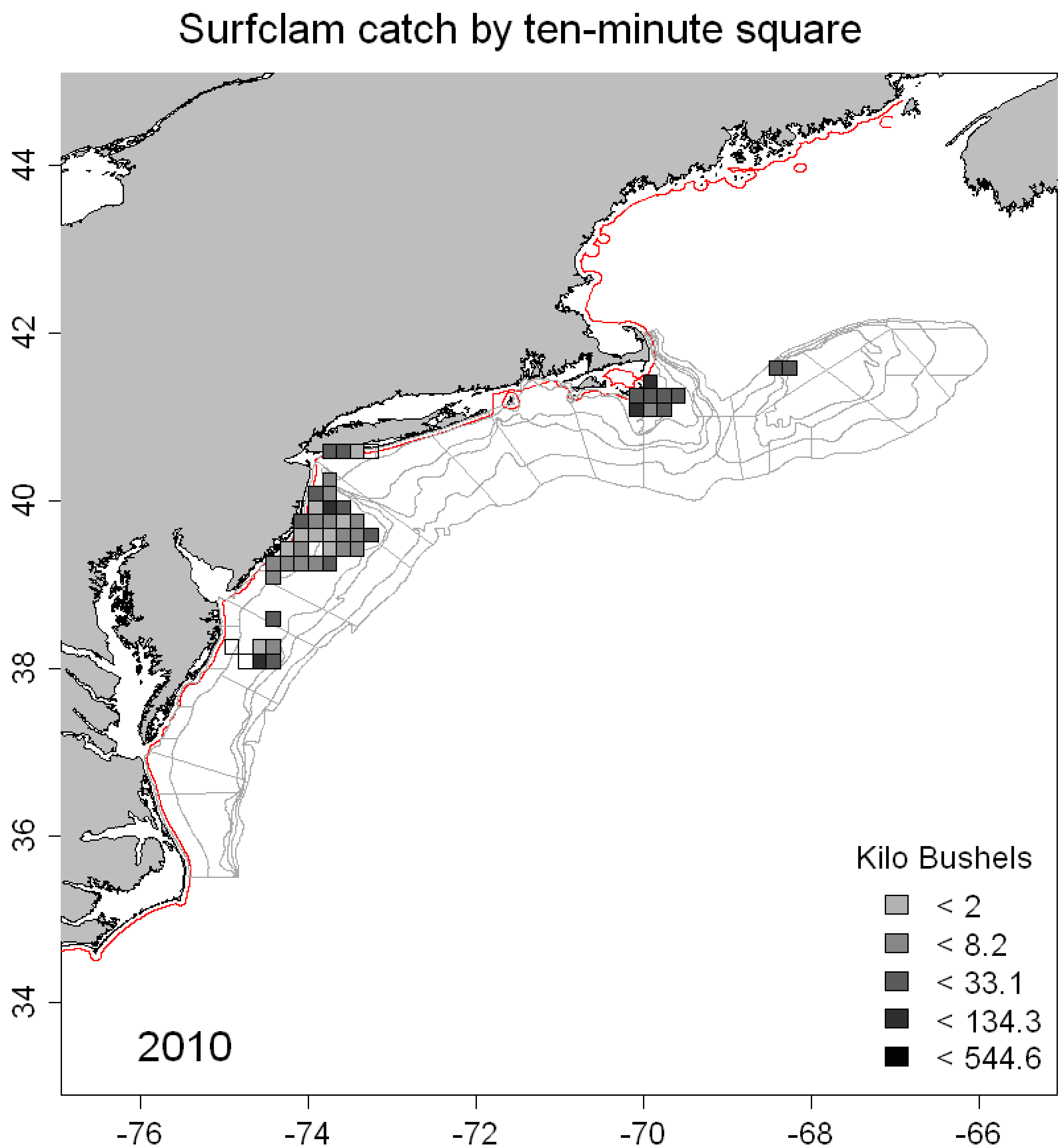
< 134.3
< 544.6


Surfclam catch by ten-minute square
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34
-76
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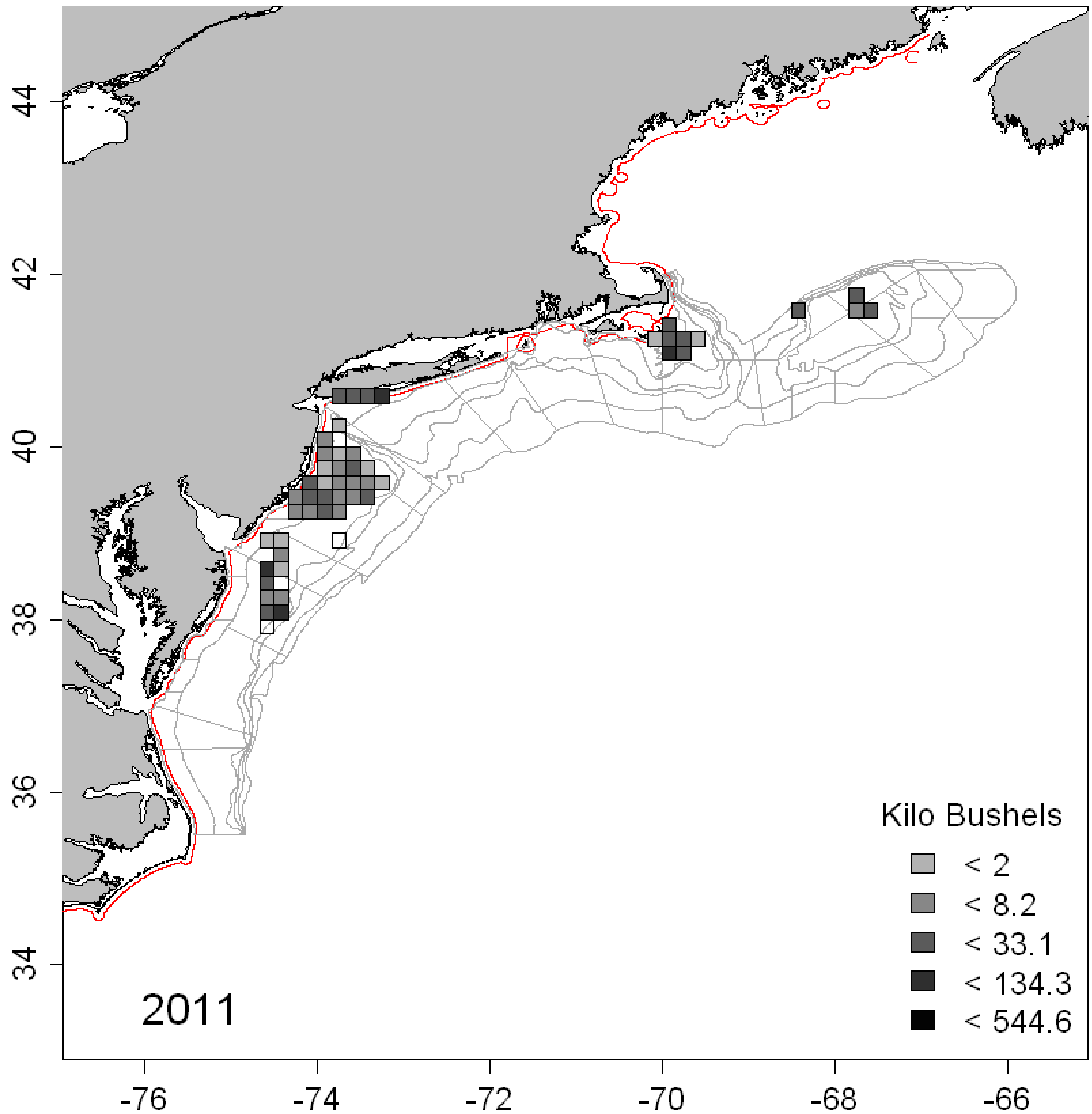
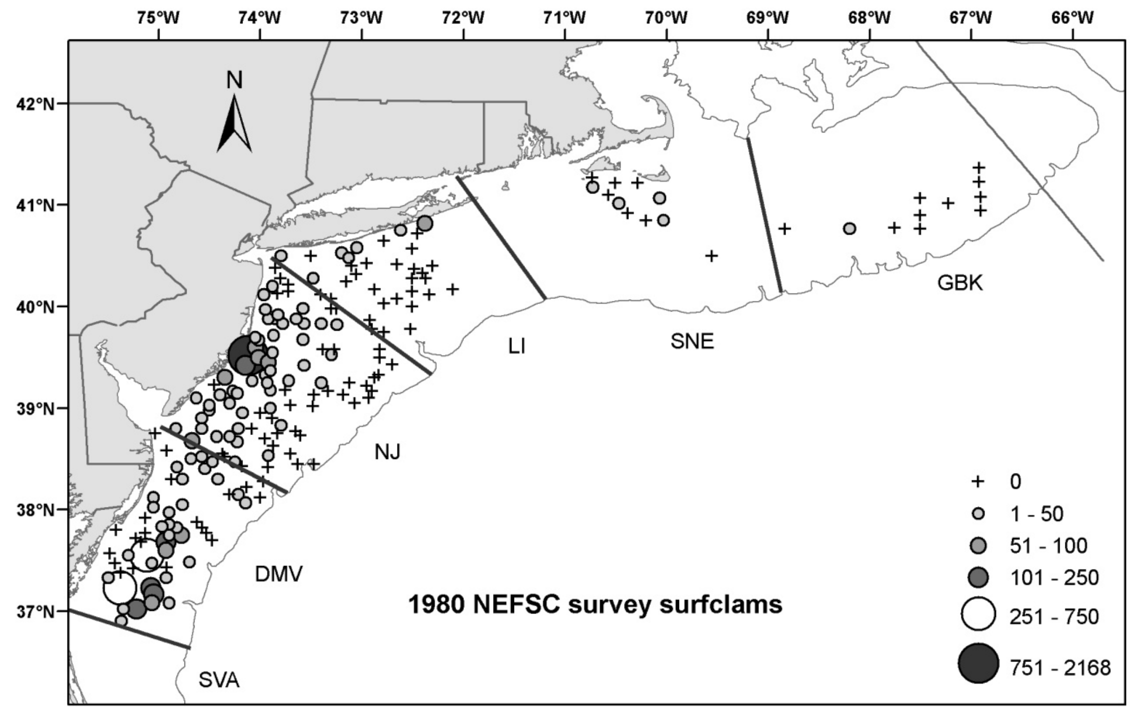
-68
-66
Kilo Bushels
< 2
< 8.2
< 33.1
< 134.3
< 544.6
2010

Surfclam catch by ten-minute square



Appendix A3: Maps of NEFSC clam surveys

(Following pages) Maps of NEFSC clam survey surfclam catches since 1980. Symbols represent number per tow of clams of all sizes. The maximum number of clams caught in a tow is the highest number in the legend.


75°W
74°W
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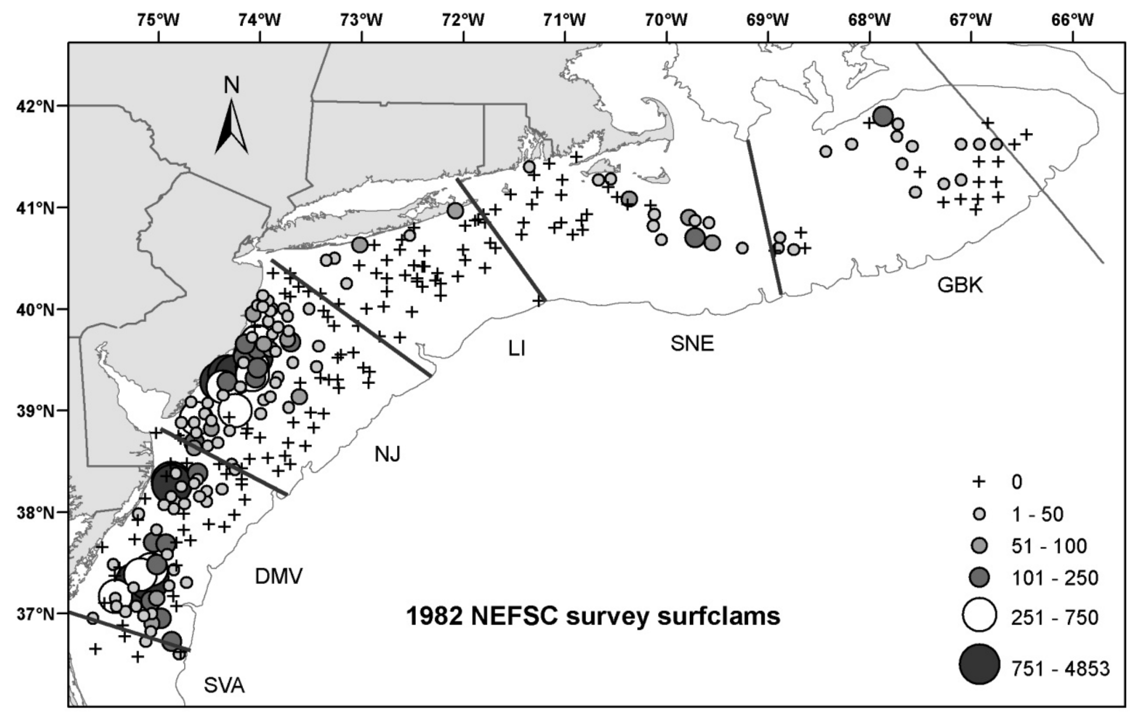
72°W
71°W
70°W
69°W
68°W
67°W
66°W
42°N
41°N
40°N
39°N
38°N
37°N
N
GBK
LI
SNE
NJ
DMV
SVA
1980 NEFSC survey surfclams
0
1 - 50
51 - 100
101 - 250
251 - 750
751 - 2168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42°N
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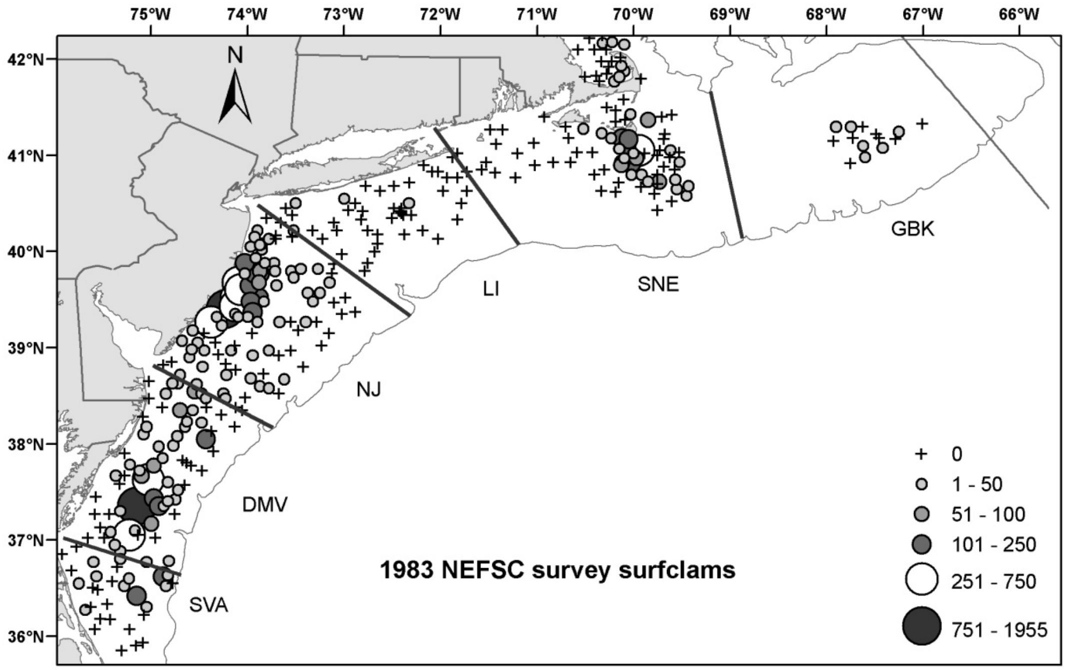
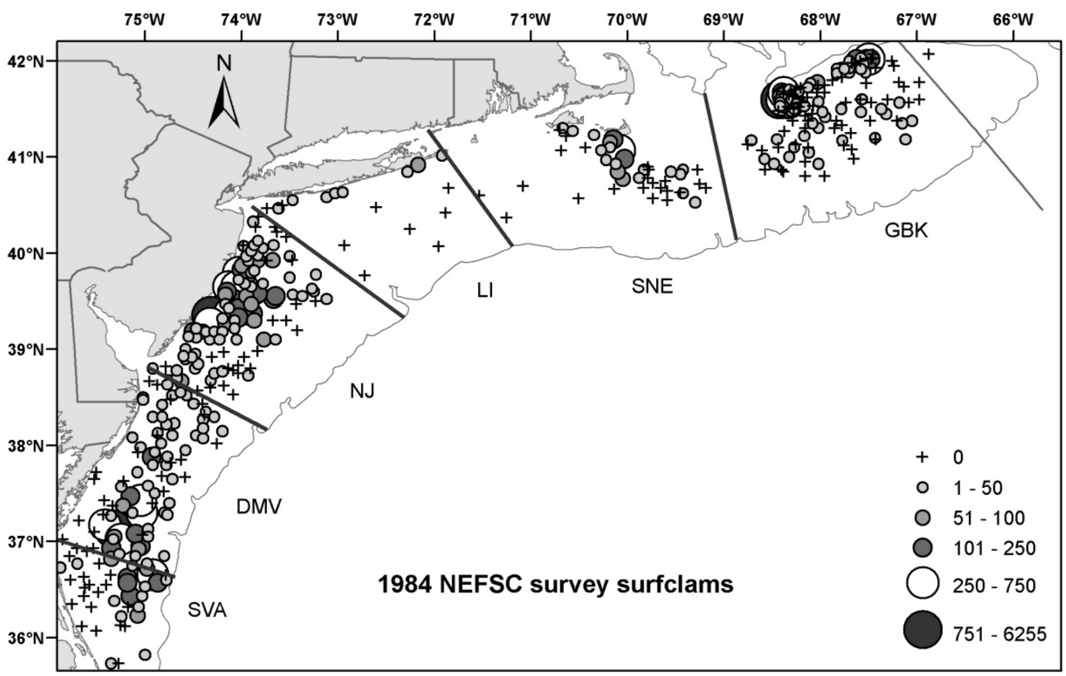
38°N
37°N
N
GBK
LI
SNE
NJ
DMV
SVA
1982 NEFSC survey surfclams
0
1 - 50
51 - 100
101 - 250
251 - 750
751 - 4853



1983 NEFSC survey surfclams
GBK
LI
SNE
NJ
DMV
SVA
0
1 - 50
51 - 100
101 - 250
251 - 750
751 - 1955



1984 NEFSC survey surfclams
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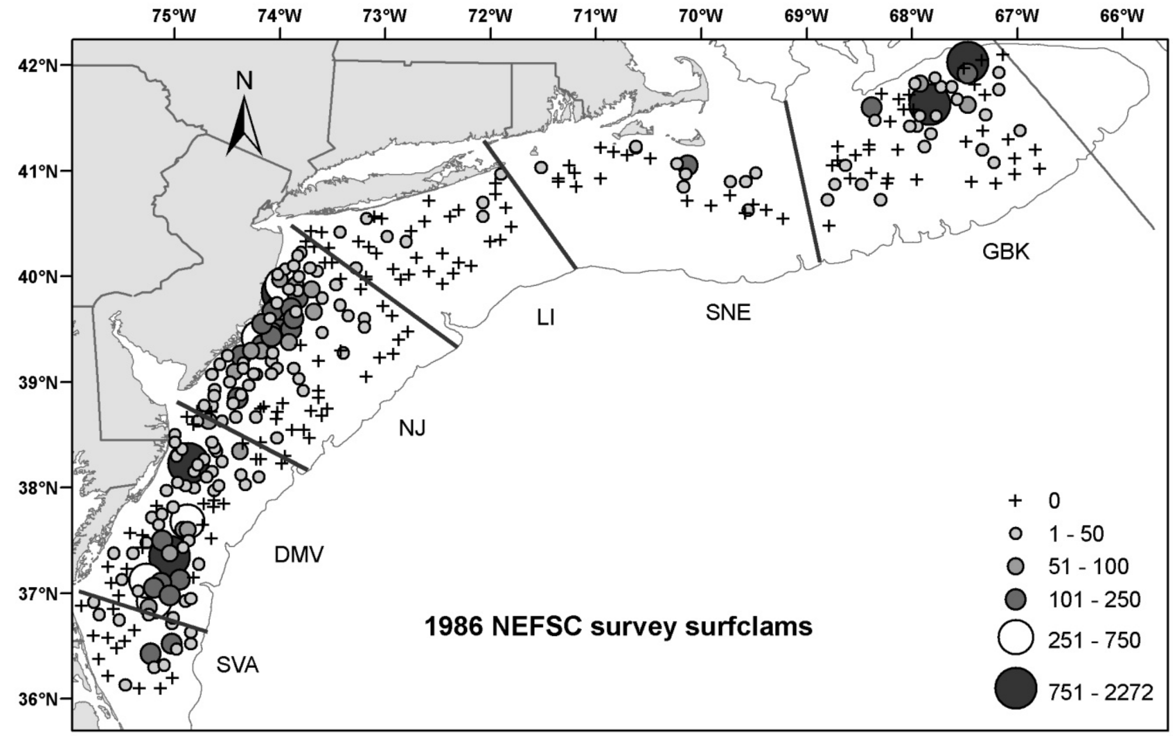
LI
SNE
NJ
DMV
SVA
0
1 - 50
51 - 100
101 - 250
250 - 750
751 - 6255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GBK
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DMV
SVA
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1 - 50
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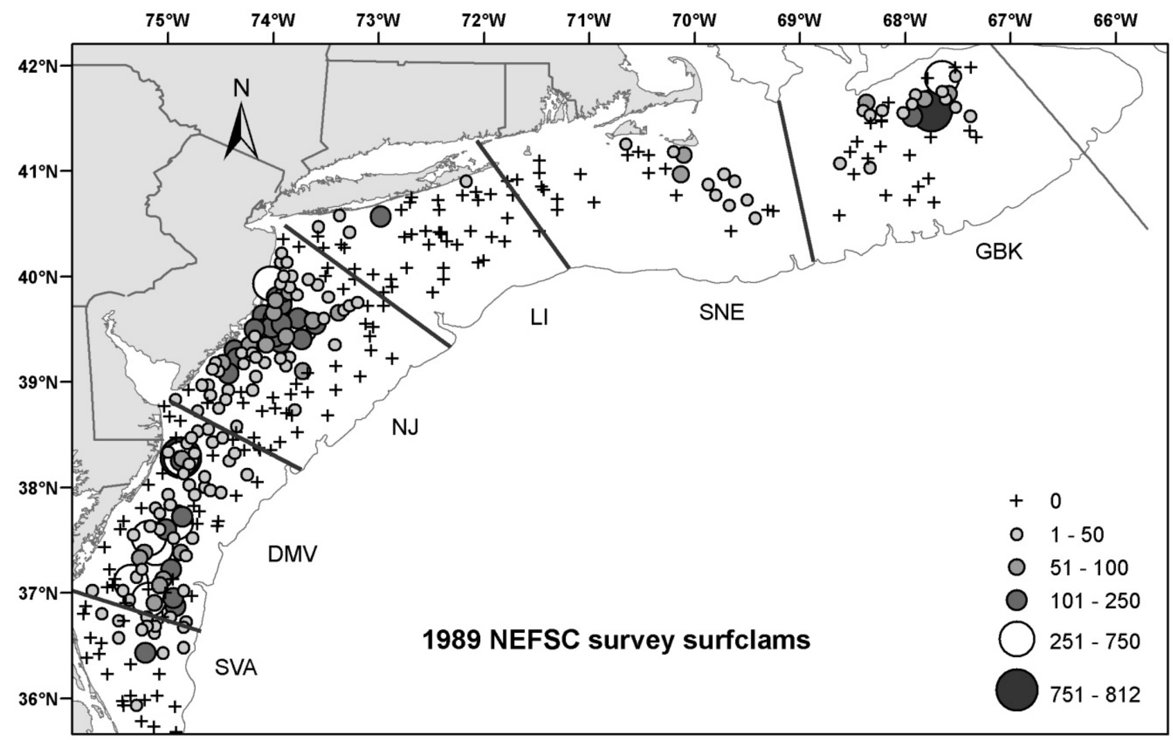
101 - 250
251 - 750
751 - 2272
1986 NEFSC survey surfclams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SVA
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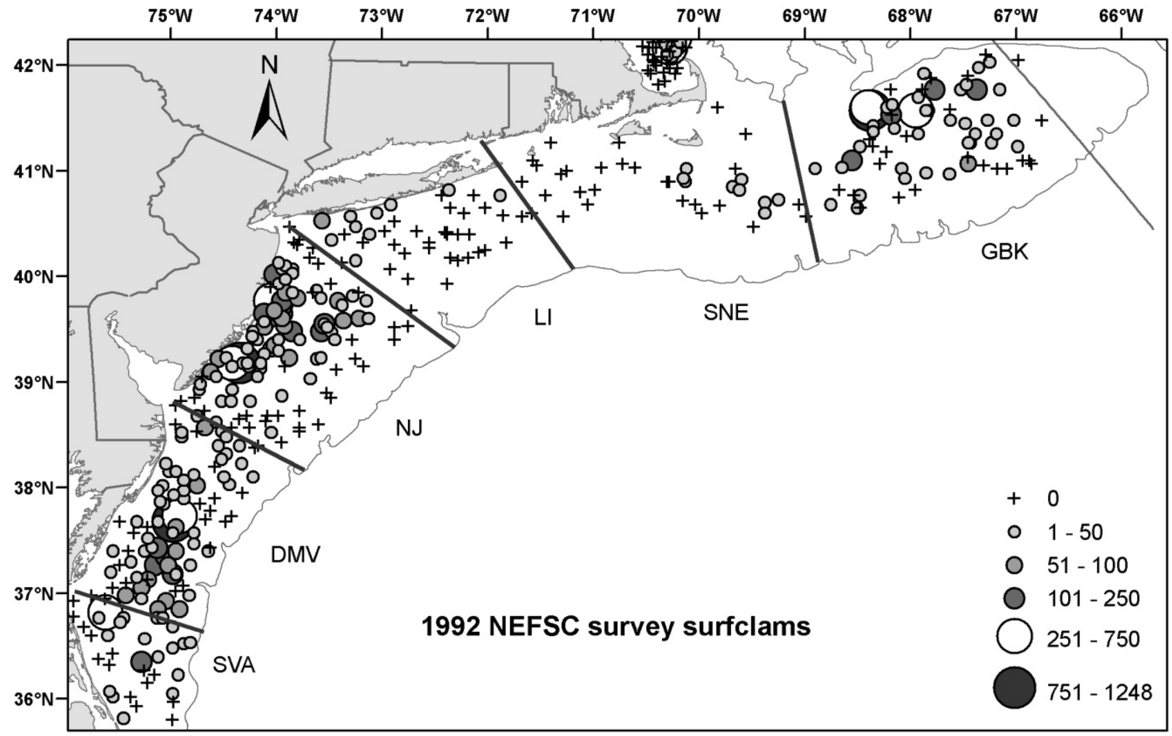
1 - 50
51 - 100
101 - 250
251 - 750
751 - 812
1989 NEFSC survey surfclams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SVA
1992 NEFSC survey surfclams
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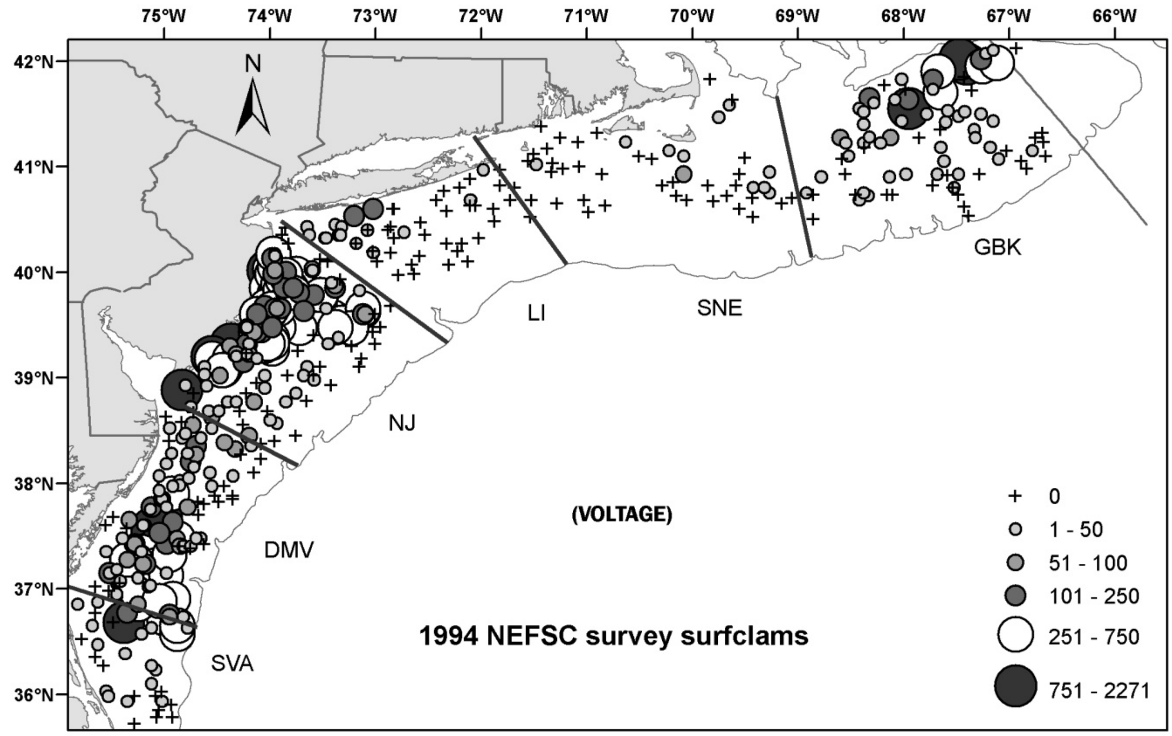
51 - 100
101 - 250
251 - 750
751 - 1248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37°N
36°N
N
LI
SNE
GBK
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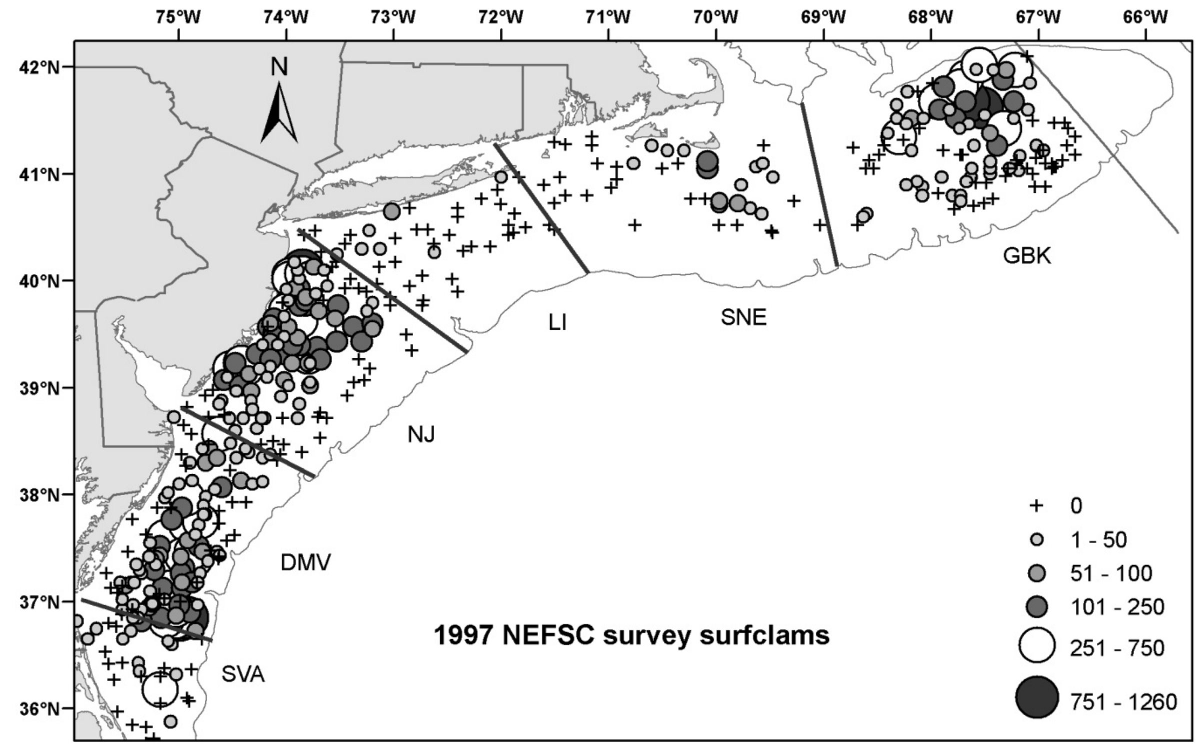
DMV
SVA
(VOLTAGE)
1994 NEFSC survey surfclams
0
1 - 50
51 - 100
101 - 250
251 - 750
751 - 2271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LI
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DMV
SVA
1997 NEFSC survey surfclams
0
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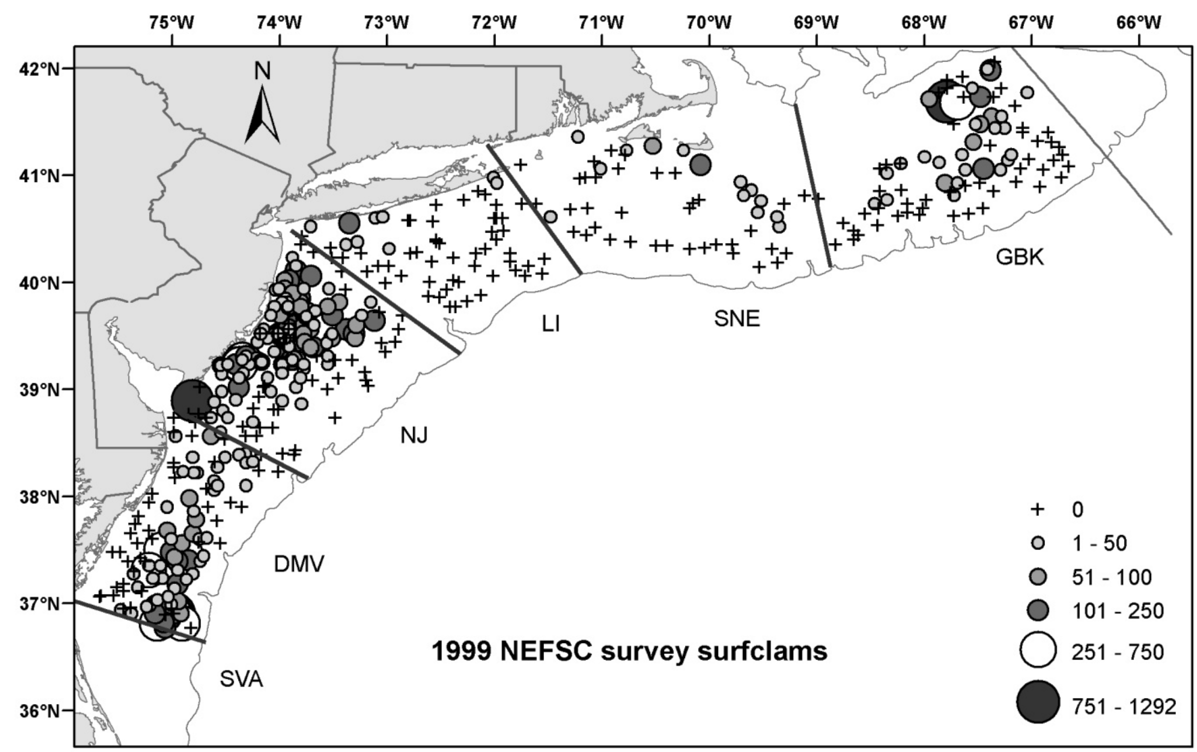
51 - 100
101 - 250
251 - 750
751 - 1260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37°N
36°N
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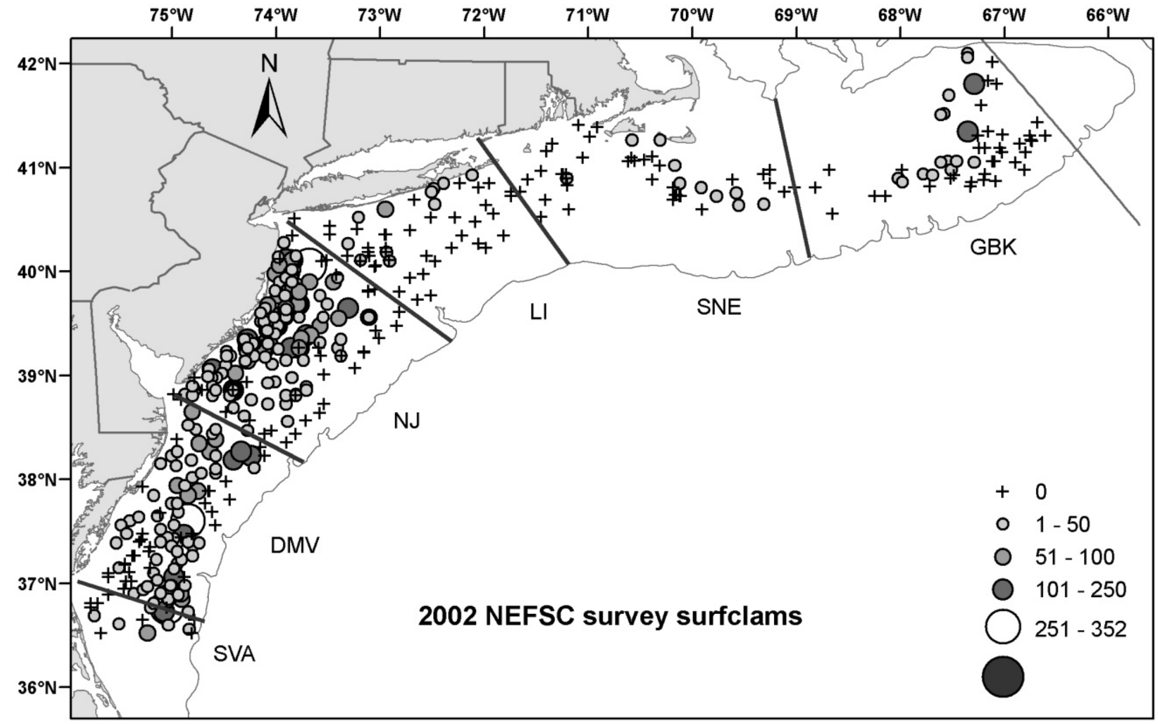
LI
SNE
GBK
NJ
DMV
SVA
1999 NEFSC survey surfclams
0
1 - 50
51 - 100
101 - 250
251 - 750
751 - 1292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37°N
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GBK
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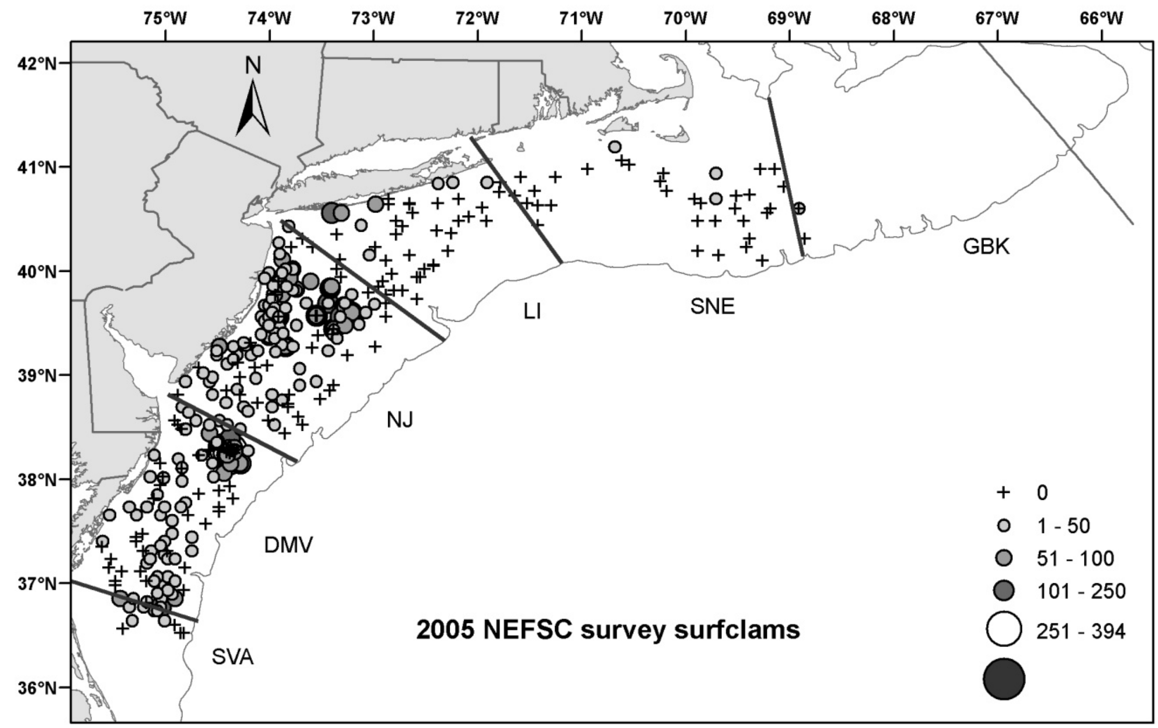
DMV
SVA
2002 NEFSC survey surfclams
0
1 - 50
51 - 100
101 - 250
251 - 352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GBK
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2005 NEFSC survey surfclams
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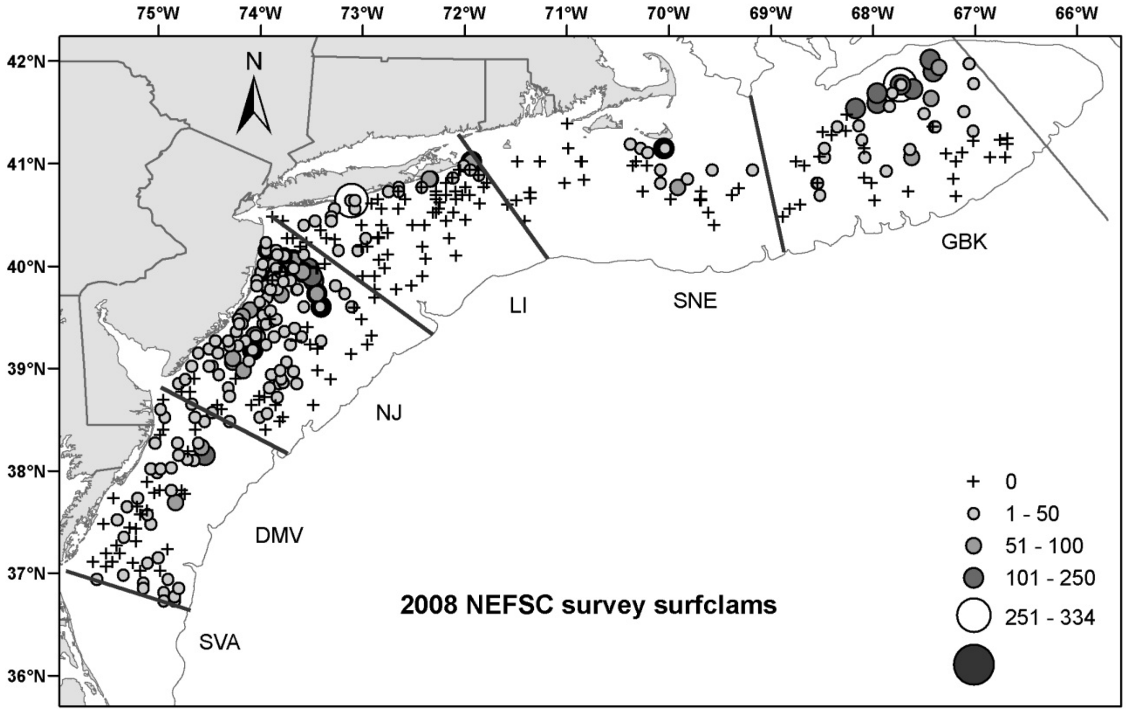
51 - 100
101 - 250
251 - 394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GBK
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SVA
2008 NEFSC survey surfclams
0
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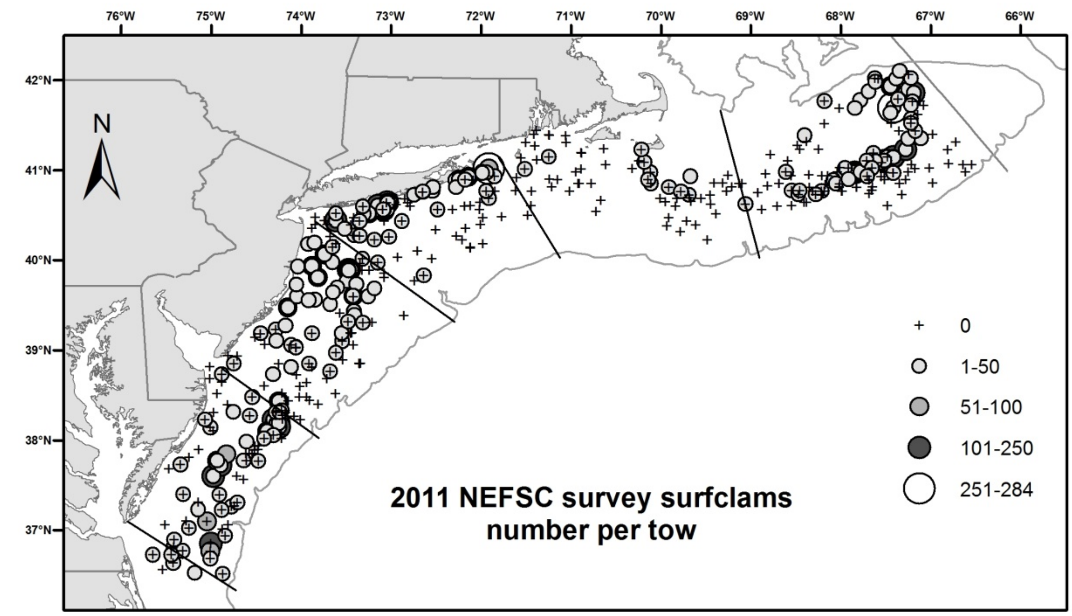
51 - 100
101 - 250
251 - 334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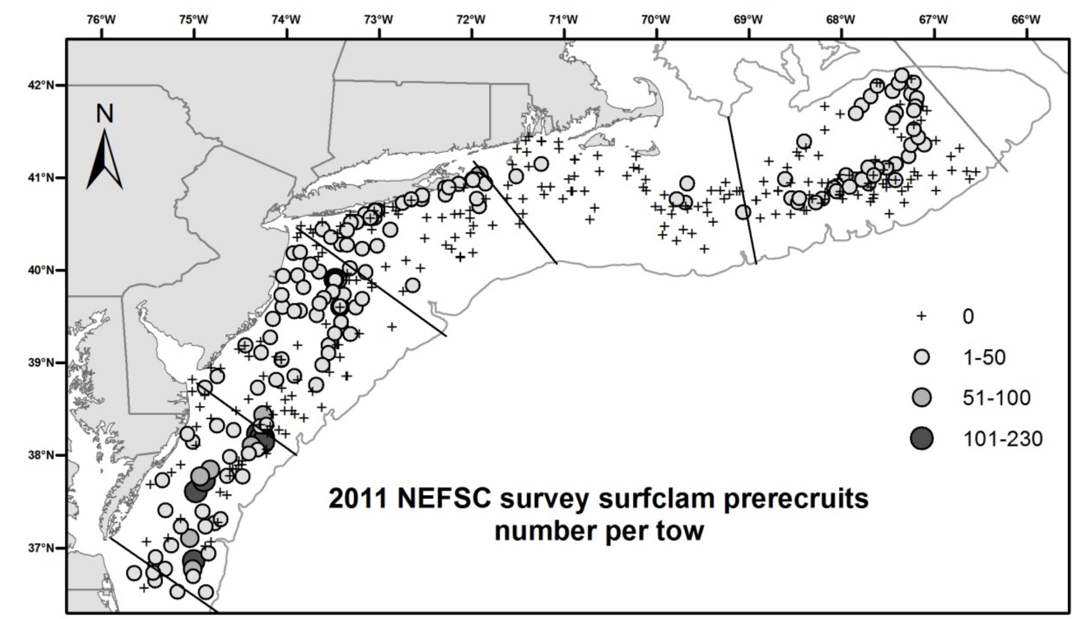
39°N
38°N
37°N
N
0
1-50
51-100
101-250
251-284
2011 NEFSC survey surfclams
number per tow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67°W
66°W
42°N
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40°N
39°N
38°N
37°N
N
0
1-50
51-100
101-230
2011 NEFSC survey surfclam prerecruits
number per tow

Appendix A4: KLAMZ methods

KLAMZ Assessment Model – Technical Documentation

The KLAMZ assessment model is based on the Deriso-Schnute delay-difference equation (Deriso 1980; Schnute 1985; Quinn and Deriso 1999). The delay-difference equation is a relatively simple and implicitly age structured approach to counting fish in either numerical or biomass units. It gives the same results as explicitly age-structured models (e.g. Leslie matrix model) if fishery selectivity is "knife-edged", if somatic growth follows the von Bertalanffy equation, and if natural mortality is the same for all age groups in each year. Knife-edge selectivity means that all individuals alive in the model during the same year experience the same fishing mortality rate.5 Natural and fishing mortality rates, growth parameters and recruitment may change from year to year, but delay-difference calculations assume that all individuals share the same mortality and growth parameters within each year. The KLAMZ model includes simple numerical models (e.g. Conser 1995) as special cases because growth can be turned off so that all calculations are in numerical units (see below).

As in many other simple models, the delay difference equation explicitly distinguishes between two age groups. In KLAMZ, the two age groups are called "new" recruits (R_t in biomass or numerical units at the beginning of year t) and "old" recruits (S_t) that together comprise the whole stock (B_t). New recruits are individuals that recruited at the beginning of the current year (at nominal age k).6 Old recruits are all older individuals in the stock (nominal ages k+1 and older, survivors from the previous year). As described above, KLAMZ assumes that new and old recruits are fully vulnerable to the fishery. The most important differences between the delay-difference and other simple models (e.g. Prager 1994; Conser 1995; Jacobson et al. 1994) are that von Bertalanffy growth is used to calculate biomass dynamics and that the delay-difference model captures transient age structure effects due to variation in recruitment, growth and mortality exactly. Transient effects on population dynamics are captured exactly because, as described above, the delay-difference equation is algebraically equivalent to an explicitly age-structured model with von Bertalanffy growth.

The KLAMZ model incorporates a few extensions to Schnute's (1985) revision of Deriso's (1980) original delay difference model. Most of the extensions facilitate tuning to a wider variety of data that anticipated in Schnute (1985). The KLAMZ model is programmed in both Excel and in C++ using AD Model Builder7 libraries. The AD Model Builder version is faster, more reliable and probably better for producing "official" stock assessment results. The Excel version is slower and implements fewer features, but the Excel version remains useful in developing prototype assessment models, teaching and for checking calculations.

The most significant disadvantage in using the KLAMZ model and other delay-difference approaches, beyond the assumption of knife-edge selectivity, is that age and length composition data are not used in tuning. However, one can argue that age composition data are used indirectly to the extent they are used to estimate growth parameters or if survey survival ratios (e.g. based on the Heinke method) are used in tuning (see below).

---

5 In applications, assumptions about knife-edge selectivity can be relaxed by assuming the model tracks "fishable", rather that total, biomass (NEFSC 2000a; 2000b). An analogous approach assigns pseudo-ages based on recruitment to the fishery so that new recruits in the model are all pseudo-age k. The synthetic cohort of fish pseudo-age k may consist of more than one biological cohort. The first pseudo-age (k) can be the predicted age at first, 50% or full recruitment based a von Bertalanffy curve and size composition data (Butler et al. 2002). The "incomplete recruitment" approach (Deriso 1980) calculates recruitment to the model in each year R_t as the weighted sum of contributions from two or more biological cohorts (year-classes) from spawning during successive years (i.e. $R_t = \sum_{a=1}^{k} r_a \Pi_{t-a}$ where k is the age at full recruitment to the fishery, r_a is the contribution of fish age k-a to the fishable stock, and Π_{t-a} is the number or biomass of fish age k-a during year t).

6 In some applications, and more generally, new recruits might be defined as individuals recruiting at the beginning or at any time during the current time step (e.g. NEFSC 1996). 6

Otter Research Ltd., Box 2040, Sydney, BC, Canada V8L 3S3 (otter@otter-rsch.com).

Population dynamics

The assumed birth date and first day of the year are assumed the same in derivation of the delay-difference equation. It is therefore natural (but not strictly necessary) to tabulate catch and other data using annual accounting periods that start on the assumed biological birthday of cohorts.

Biomass dynamics

As implemented in the KLAMZ model, Schnute's (1985) delay-difference equation is:

$$B_{t+1} = (1+\rho)\,\tau_t\, B_t - \rho\,\tau_t\,\tau_{t-1}\, B_{t-1} + R_{t+1} - \rho\,\tau_t\, J_t\, R_t$$

where B_t is total biomass of individuals at the beginning of year t; ρ is Ford's growth coefficient (see below); $\tau_t=exp(-Z_t)=exp[-(F_t+M_t)]$ is the fraction of the stock that survived in year t, Z_t, F_t, and M_t are instantaneous rates for total, fishing and natural mortality; and R_t is the biomass of new recruits (at age k) at the beginning of the year. The natural mortality rate M_t may vary over time. Instantaneous mortality rates in KLAMZ model calculations are biomass-weighted averages if von Bertalanffy growth is turned on in the model. However, biomass-weighted mortality estimates in KLAMZ are the same as rates for numerical estimates under the assumption of knife-edge selectivity because all individuals are fully recruited. The growth parameter $J_t = w_{t-1,k-1} / w_{t,k}$ is the ratio of mean weight one year before recruitment (age k-1 in year t-1) and mean weight at recruitment (age k in year t).

It is not necessary to specify body weights at and prior to recruitment in the KLAMZ model (parameters v_{t-1} and V_t in Schnute 1985) because the ratio J_t and recruitment biomass contain the same information. Schnute's (1985) original delay difference equation is:

$$B_{t+1} = (1+\rho)\,\tau_t\, B_t - \rho\,\tau_t\tau_{t-1}\, B_{t-1} + w_{t+1,k}N_{t+1} - \rho\tau_t w_{t-1,k-1}\, N_t$$

To derive the equation used in KLAMZ, substitute recruitment biomass R_{t+1} for the product $w_{t+1,k}N_{t+1,k}$ and adjusted recruitment biomass $J_t R_t = (w_{t-1,k-1}/w_{t,k})\, w_{t,k}\, N_{t,k} =$
$w_{t-1,k-1}\, N_t$ in the last term on the right hand side. The advantage in using the alternate parameterization for biomass dynamic calculations in KLAMZ is that recruitment is estimated directly in units of biomass and the number of growth parameters is reduced. The disadvantage is that numbers of recruits are not estimated directly by the model. When required, numerical recruitments must be calculated externally as the ratio of estimated recruitment biomass and the average body weight for new recruits.

Numerical population dynamics

Growth can be turned on off so that abundance, rather than biomass, is tracked in the KLAMZ model. Set J_t=1 and ρ=0 in the delay difference equation, and use N_t (for numbers) in place of B_t to get:

$$N_{t+1} = \tau_t\, N_t + R_{t+1}$$

Mathematically, the assumption J_t=1 means that no growth occurs the assumption ρ=0 means that the von Bertalanffy K parameter is infinitely large (Schnute 1985). All tuning and population dynamics calculations in KLAMZ for biomass dynamics are also valid for numerical dynamics.

Growth

As described in Schnute (1985), biomass calculations in the KLAMZ model are based on Schnute and Fournier's (1980) re-parameterization of the von Bertalanffy growth model:

$$w_a = w_{k-1} + (w_k - w_{k-1})\,(1+\rho^{1+a-k})\,/\,(1-\rho)$$

where w_k=V and w_{k-1}=v. Schnute and Fournier's (1980) growth model is the same as the traditional von Bertalanffy growth model {$W_a= W_{max}\,[1 - exp(-K(a-t_{zero})]$ where W_{max}, K and t_{zero} are parameters}. The two growth models are the same because $W_{max} = (w_k - \rho\, w_{k-1})/(1-\rho)$, $K = -ln(\rho)$ and $t_{zero} = ln[(w_k - w_{k-1})/(w_k - \rho\, w_{k-1})]\,/\,ln(\rho)$.

In the KLAMZ model, the growth parameters J_t can vary with time but ρ is constant. Use of time-variable J_t values with ρ is constant is the same as assuming that the von Bertalanffy parameters W_{max} and t_{zero} change over time. Many growth patterns can be mimicked by changing W_{max} and t_{zero} (Overholtz et al., 2003). K is a parameter in the C++ version and, in principal, estimable. However, in most cases it is necessary to use external estimates of growth parameters as constants in KLAMZ.

Instantaneous growth rates

Instantaneous growth rate (IGR) calculations in the KLAMZ model are an extension to the original Deriso-Schnute delay difference model. IGRs are used extensively in KLAMZ for calculating catch biomass and projecting stock biomass forward to the time at which surveys occur. The IGR for new recruits depends only on growth parameters:

$$G_t^{New} = \ln\left(\frac{w_{k+1,t+1}}{w_{k,t}}\right) = \ln(1+\rho-\rho J_t)$$

IGR for old recruits is a biomass-weighted average that depends on the current age structure and growth parameters. It can be calculated easily by projecting biomass of old recruits $S_t=B_t-R_t$ (escapement) forward one year with no mortality:

$$S_t^* = (1+\rho)S_t - \rho\tau_{t-1}B_{t-1}$$

where the asterisk (*) means just prior to the start of the subsequent year t+1. By definition, the IGR for old recruits in year t is $G_t^{Old} = \ln\left(S_t^*/S_t\right)$. Dividing by S_t gives:

$$G_t^{Old} = \ln\left[(1+\rho)-\rho\tau_{t-1}\frac{B_{t-1}}{S_t}\right]$$

IGR for the entire stock is the biomass weighted average of the IGR values for new and old recruits:

$$G_t = \frac{R_t G_t^{New} + S_t G_t^{Old}}{B_t}$$

All IGR values are zero if growth is turned off.

Recruitment

In the Excel version of the KLAMZ model, annual recruitments are calculated $R_t = e^{\Omega_t}$ where Ω_t is a log transformed annual recruitment parameter, which is estimated in the model. In the C++ version, recruitments are calculated based on two log geometric mean recruitment parameters (μ, ι_t), and a set of annual log scale deviation parameters (ω_t):

$$\Omega_t = \mu + \iota_t + \omega_t$$

The parameter ι_t is an offset for a step function that may be zero for all years or zero for years up to a user-specified "change year" and any value (usually estimated) afterward. The user must specify the change year, which cannot be estimated. The change year might be chosen based on auxiliary information outside the model, preliminary model fits or by carrying out a set of runs using sequential change year values and to choosing the change year that provides the best fit to the data.

The deviations ω_t are constrained to average zero.8 With the constraint, for example, estimation of μ and the set of ω_t values (1+ n years parameters) is equivalent to estimation of the smaller set (n years) of Ω_t values.

Recruitment as a rate

Recruitment is assumed in the KLAMZ model to occur at the beginning of the year. However, it is often useful to calculate recruitment biomass as an instantaneous rate for comparison to instantaneous rates for natural mortality, fishing mortality and growth. If recruitment were a continuous process, then the instantaneous rate for year t could be calculated:

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8 The constraint is implemented by adding $L = \lambda\overline{\varpi}^2$ (where $\overline{\varpi}$ is the average deviation) to the objective function, generally with a high weighting factor (λ = 1000) so that the constraint is binding.

$$r_t = \ln\left(\frac{B_{t+1}}{B_t}\right) + M_t + F_t - G_t$$

The recruitment rate can not be calculated for the last year in the model because St is not available. The KLAMZ model calculates recruitment rates for all other years automatically.

Natural mortality

Natural mortality rates (M_t) are assumed constant in the Excel version of the KLAMZ model. In the C++ version, natural mortality rates may be estimated as a constant value or as a set of values that vary with time. In the model:

$$M_t = me^{\varpi_t}$$

where $m=exp(\pi)$ is the geometric mean natural mortality rate, π is a model parameter that may be estimated (in principal but not in practical terms), and ϖ_t is the log scale year-specific deviation. Deviations may be zero (turned off) so that M_t is constant, may vary in a random fashion due to autocorrelated or independent process errors, or may based on a covariate.9 Model scenarios with zero recruitment may be initializing the parameter π to a small value (e.g. 10^{-16}) and not estimating it.

Random natural mortality process errors are effects due to predation, disease, parasitism, ocean conditions or other factors that may vary over time but are not included in the model. Calculations are basically the same as for survey process errors (see below).

Natural mortality rate covariate calculations are similar to survey covariate calculations (see below) except that the *user should standardize covariates to average zero over the time period included in the model*:

$$\kappa_t = K_t - \overline{K}$$

where κ_t is the standardized covariate, K_t is the original value, and $\overline{K}$ is the mean of the original covariate for the years in the model. *Standardization to mean zero is important because otherwise m is not the geometric mean natural mortality rate* (the convention is important in some calculations, see text).

Log scale deviations that represent variability around the geometric mean are calculated:

$$\varpi_t = \sum_{j=1}^{n} p_j \kappa_t$$

where n is the number of covariates and p_j is the parameter for covariate j. These conventions mean that the units for the covariate parameter p_j are 1/units of the original covariate, the parameter p_j measures the log scale effect of changing the covariate by one unit, and the parameter m is the log scale geometric mean.

Fishing mortality and catch

Fishing mortality rates (F_t) are calculated so that predicted and observed catch data (landings plus estimated discards in units of weight) "agree" to the extent specified by the user. It is not necessary, however, to assume that catches are measured accurately (see "Observed and predicted catch").

Fishing mortality rate calculations in Schnute (1985) are exact but relating fishing mortality to catch in weight is complicated by continuous somatic growth throughout the year as fishing occurs. The KLAMZ model uses a generalized catch equation that incorporates continuous growth through the fishing season. By the definition of instantaneous rates, the catch equation expresses catch as the product:

9 Another approach to using time dependent natural mortality rates is to treat estimates of predator consumption as discarded catch (see "Predator consumption as discard data"). In addition, estimates of predator abundance can be used in fishing effort calculations (see "Predator data as fishing effort").

$$\hat{C}_t = F_t \overline{B}_t$$

where $\hat{C}_t$ is predicted catch weight (landings plus discard) and $\overline{B}_t$ is average biomass.

Following Chapman (1971) and Zhang and Sullivan (1988), let $X_t = G_t - F_t - M_t$ be the net instantaneous rate of change for biomass.*10* If the rates for growth and mortality are equal, then $X_t=0$, $\overline{B}_t = B_t$ and $C_t = F_t B_t$. If the growth rate G_t exceeds the combined rates of natural and fishing mortality ($F_t + M_t$), then $X_t > 0$. If mortality exceeds growth, then $X_t < 0$. In either case, with $X_t \neq 0$, average biomass is computed:

$$\overline{B}_t \approx -\frac{\left(1 - e^{X_t}\right) B_t}{X_t}$$

When $X_t \neq 0$, the expression for $\overline{B}_t$ is an approximation because G_t approximates the rate of change in mean body weight due to von Bertalanffy growth. However, the approximation is reasonably accurate and preferable to calculating catch biomass in the delay-difference model with the traditional catch equation that ignores growth during the fishing season.11 Average biomass can be calculated for new recruits, old recruits or for the whole stock by using either G_t^{New}, G_t^{Old} or G_t.

In the KLAMZ model, the modified catch equation may be solved analytically for F_t given C_t, B_t, G_t and M_t (see the "Calculating F_t" section below). Alternatively, fishing mortality rates can be calculated using a log geometric mean parameter (Φ) and a set of annual log scale deviation parameters (ψ_t):

$$F_t = e^{\Phi + \psi_t}$$

where the deviations ψ_t are constrained to average zero. When the catch equation is solved analytically, catches must be assumed known without error but the analytical option is useful when catch is zero or very near zero, or the range of fishing mortality rates is so large (e.g. minimum F=0.000001 to maximum F=3) that numerical problems occur with the alternative approach. The analytical approach is also useful if the user wants to reduce the number of parameters estimated by nonlinear optimization. In any case, the two methods should give the same results for catches known without error.

Surplus production

Annual surplus production is calculated "exactly" by projecting biomass at the beginning of each year forward with no fishing mortality:

$$B_t^* = (1+\rho)\, e^{-M}\, B_t - \rho\, e^{-2M} B_{t-2} - \rho\, e^{-M}\, J_{t-1}\, R_{t-1} + R_t$$

By definition, surplus production $P_t = B^*_t - B_t$ (Jacobson et al. 2002).

Per recruit modeling

Per recruit model calculations in the Excel version of the KLAMZ simulate the life of a hypothetical cohort of arbitrary size (e.g. R=1000) starting at age k with constant M_t, F (survival) and growth (ρ and average J ($\overline{J}$)) in a population initially at zero biomass. In the first year:

$$B_1 = R$$

In the second year:

$$B_2 = (1+\rho)\,\tau\, B_1 - \rho\,\tau\,\overline{J}\, R_1$$

In the third and subsequent years:

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10 By convention, the instantaneous rates G_t, F_t and M_t are always expressed as numbers ≥ 0.

11 The traditional catch equation $C_t = F_t(1 - e^{-Z_t}) B_t / Z_t$ where $Z_t = F_t + M_t$ underestimates catch biomass for a given level of fishing mortality F_t and overestimates F_t for a given level of catch biomass. The errors can be substantial for fast growing fish, particularly if recent recruitments were strong.

$$B_{t+1} = (1 + \rho)\,\tau\,B_t - \rho\,\tau^2\,B_{t-1}$$

This iterative calculation is carried out until the sum of lifetime cohort biomass from one iteration to the next changes by less than a small amount (0.0001). Total lifetime biomass, spawning biomass and yield in weight are calculated by summing biomass, spawning biomass and yield over the lifetime of the cohort. Lifetime biomass, spawning biomass and yield per recruit are calculated by dividing totals by initial recruitment (*R*).

Status determination variables

The user may specify a range of years (e.g. the last three years) to use in calculating recent average fishing mortality $\overline{F}_{\mathrm{Re}\,cent}$ and biomass $\overline{B}_{\mathrm{Re}\,cent}$ levels. These status determination variables are used in calculation of status ratios such as $\overline{F}_{\mathrm{Re}\,cent} / F_{MSY}$ and $\overline{B}_{\mathrm{Re}\,cent}$ /B_{MSY}.

Goodness of Fit and Parameter Estimation

Parameters estimated in the KLAMZ model are chosen to minimize an objective function based on a sum of weighted negative log likelihood (NLL) components:

$$\Xi = \sum_{v=1}^{N_\Xi} \lambda_v L_v$$

where N_Ξ is the number of NLL components (L_v) and the λ_v are emphasis factors used as weights. The objective function Ξ may be viewed as a NLL or a negative log posterior (NLP) distribution, depending on the nature of the individual L_v components and modeling approach. Except during sensitivity analyses, weighting factors for objective function components (λ_v) are usually set to one. An arbitrarily large weighting factor (e.g. λ_v =1000) is used for "hard" constraints that must be satisfied in the model. Arbitrarily small weighting factors (e.g. λ_v =0.0001) can be used for "soft" model-based constraints. For example, an internally estimated spawner-recruit curve or surplus production curve might be estimated with a small weighting factor to summarize stock-recruit or surplus production results with minimal influence on biomass, fishing mortality and other estimates from the model. Use of a small weighting factor for an internally estimated surplus production or stock-recruit curve is equivalent to fitting a curve to model estimates of biomass and recruitment or surplus production in the output file, after the model is fit (Jacobson et al. 2002).

Likelihood component weights vs. observation-specific weights

Likelihood component weights (λ_v) apply to entire NLL components. Entire components are often computed as the sum of a number of individual NLL terms. The NLL for an entire survey, for example, is composed of NLL terms for each of the annual survey observations. In KLAMZ, observation-specific (for data) or instance-specific (for constraints or prior information) weights (usually w_j for observation or instance *j*) can be specified as well. Observation-specific weights for a survey, for example, might be use to increase or decrease the importance of one or more observations in calculating goodness of fit.

NLL kernels

NLL components in KLAMZ are generally programmed as "concentrated likelihoods" to avoid calculation of values that do not affect derivatives of the objective function.12 For x~N(μ,σ^2), the complete NLL for one observation is:

12 Unfortunately, concentrated likelihood calculations cannot be used with MCMC and other Bayesian approaches to characterizing posterior distributions. Therefore, in the near future, concentrated NLL calculations will be replaced by calculations for the entire NLL. At present, MCMC calculations in KLAMZ are not useful.

$$L = \ln(\sigma) + \ln\left(\sqrt{2\pi}\right) + 0.5\left(\frac{x-u}{\sigma}\right)^2$$

The constant $\ln\left(\sqrt{2\pi}\right)$ can always be omitted because it does not affect derivatives. If the standard deviation is known or assumed known, then ln(σ) can be omitted as well because it is a constant that does not affect derivatives. In such cases, the concentrated negative log likelihood is:

$$L = 0.5\left(\frac{x-\mu}{\sigma}\right)^2$$

If there are N observations with possible different variances (known or assumed known) and possibly different expected values:

$$L = 0.5\sum_{i=1}^{N}\left(\frac{x_i-\mu_i}{\sigma_i}\right)^2$$

If the standard deviation for a normally distributed quantity is not known and is (in effect) estimated by the model, then one of two equivalent calculations is used. Both approaches assume that all observations have the same variance and standard deviation. The first approach is used when all observations have the same weight in the likelihood:

$$L = 0.5N\ln\left[\sum_{i=1}^{N}(x_i-u)^2\right]$$

where N is the number of observations. The second approach is equivalent but used when the weights for each observation (w_i) may differ:

$$L = \sum_{i=1}^{N} w_i\left[\ln(\sigma) + 0.5\left(\frac{x_i-u}{\sigma}\right)^2\right]$$

In the latter case, the maximum likelihood estimator:

$$\hat{\sigma} = \sqrt{\frac{\sum_{i=1}^{N}(x_i-\hat{x})^2}{N}}$$

(where $\hat{x}$ is the average or predicted value from the model) is used for σ. The maximum likelihood estimator is biased by $N/(N-d_f)$ where d_f is degrees of freedom for the model. The bias may be significant for small sample sizes but d_f is usually unknown.

Landings, discards, catch

Discards are from external estimates (d_t) supplied by the user. If $d_t \geq 0$, then the data are used as the ratio of discard to landed catch so that:

$$D_t = L_t\Delta_t$$

where $\Delta_t = D_t/L_t$ is the discard ratio. If $d_t < 0$ then the data are treated as discard in units of weight:

$$D_t = abs(d_t).$$

In either case, total catch is the sum of discards and landed catch ($C_t = L_t + D_t$). It is possible to use discards in weight $d_t < 0$ for some years and discard as proportions $d_t > 0$ for other years in the same model run. If catches are estimated (see below) so that the estimated catch $\hat{C}_t$ does not necessarily equal observed landings plus discard, then estimated landings are computed:

$$\hat{L}_t = \frac{\hat{C}_t}{1+\Delta_t}$$

and estimated discards are:

$$\hat{D}_t = \Delta_t \hat{L}_t .$$

Calculating F_t

As described above, fishing mortality rates may be estimated based on the parameters Φ and ψ_t to satisfy a NLL for observed and predicted catches:

$$L = 0.5 \sum_{t=0}^{N} w_t \left(\frac{\hat{C}_t - C_t}{\kappa_t} \right)^2$$

where the standard error $\kappa_t = CV_{catch} \hat{C}_t$ with CV_{catch} and weights are w_t supplied by the user. The weights can be used, for example, if catch data in some years are less precise than in others. Using observation specific weights, any or every catch in the time series can potentially be estimated.

The other approach to calculating F_t values is by solving the generalized catch equation (see above) iteratively. Subtracting predicted catch from the generalized catch equation gives:

$$g(F_t) = C_t + \frac{F_t\left(1-e^{X_t}\right)}{X_t} B_t = 0$$

where X_t=G_t-M_t-F_t. If X_t=0, then $\overline{B_t} = B_t$ and F_t=C_t/B_t.

If $X_t \neq 0$, then the Newton-Raphson algorithm is used to solve for F_t (Kennedy and Gentle 1980). At each iteration of the algorithm, the current estimate F_t^i is updated using:

$$F_t^{i+1} = F_t^i - \frac{g\left(F_t^i\right)}{g'\left(F_t^i\right)}$$

where $g'\left(F_t^i\right)$ is the derivative F_t^i. Omitting subscripts, the derivative is:

$$g^{'}(F) = -\frac{Be^{-F}\left[\left(e^F - e^{\gamma}\right)\gamma + e^{\gamma} F \gamma - e^{\gamma} F^2\right]}{X^2}$$

where γ=G-M_t. Iterations continue until $g\left(F_t^i\right)$ and $abs\left[g\left(F_t^{i+1}\right) - g\left(F_t^{i+1}\right)\right]$ are both less than a small number (e.g. ≤ 0.00001).

Initial values are important in algorithms that solve the catch equation numerically (Sims 1982). If M_t+F_t > G_t so that $X_t < 0$, then the initial value F_t^0 is calculated according to Sims (1982). If M_t+F_t < G_t so that $X_t > 0$, then initial values are calculated based on a generalized version of Pope's cohort analysis (Zhang and Sullivan 1988):

$$F_t^0 = \gamma_t - \ln\left[\frac{\left(B_t e^{0.5\gamma_t} - C_t\right)e^{0.5\gamma_t}}{B_t}\right]$$

F for landings versus F for discards

The total fishing mortality rate for each year can be partitioned into a component due to landed catch ${}^{L}F_t = \frac{D_t}{C_t} F_t$, and a component due to discard ${}^{D}F_t = \frac{L_t}{C_t} F_t$.

Predator consumption as discard data

In modeling population dynamics of prey species, estimates of predator consumption can be treated like discard in the KLAMZ model as a means for introducing time dependent natural mortality. Consider a hypothetical example with consumption data (mt y^{-1}) for three important predators. If the aggregate consumption data are included in the model as "discards", then the fishing mortality rate for discards ${}^{d}F_t$ (see above) would be an estimate of the component of natural mortality due to the three predators. In using this approach, the average level of natural mortality m would normally be reduced (e.g. so that $m_{new} + {}^{d}\overline{F} = m_{old}$) or estimated to account for the portion of natural mortality attributed to bycatch.

Surplus production calculations are harder to interpret if predator consumption is treated as discard data because surplus production calculations assume that F_t=0 (see above) and because surplus production is defined as the change in biomass from one year to the next in the absence of fishing (i.e. no landings or bycatch). However, it may be useful to compare surplus production at a given level of biomass from runs with and without consumption data as a means of estimating maximum changes in potential fishery yield if the selected predators were eliminated (assuming no change in disease, growth rates, predation by other predators, etc.).

Effort calculations

Fishing mortality rates can be tuned to fishing effort data for the "landed" catch (i.e. excluding discards). Years with non-zero fishing effort used in the model must also have landings greater than zero. Assuming that effort data are lognormally distributed, the NLL for fishing effort is:

$$NLL = 0.5\sum_{y=1}^{n_{eff}} w_y \left[\frac{\ln\left(E_y / \hat{E}_y\right)}{\sigma} \right]^2$$

where w_y is an observation-specific weight, n_{eff} is the number of active effort observations (i.e. with $w_y > 0$), E_y and $\overline{E}_y$ are observed and predicted fishing effort data, and the log scale variance σ is a constant calculated from a user-specified CV.

Predicted fishing effort data are calculated:

$$\hat{E}_y = \zeta F_y^{\vartheta}$$

where $\zeta = e^u$, $\vartheta = e^b$, and u and b are parameters estimated by the model. If the parameter b is not estimated, then ϑ=1 so that the relationship between fishing effort and fishing mortality is linear. If the parameter b is estimated, then $\vartheta \neq 1$ and the relationship is a power function.

Predator data as fishing effort

As described under "Predator consumption as discard data", predator consumption data can be treated as discard. If predator abundance data are available as well, and assuming that mortality due predators is a linear function of the predator-prey ratio, then both types of data may be used together to estimate natural mortality. The trick is to: 1) enter the predator abundance data as fishing effort; 2) enter the actual fishery landings as "discard"; 3) enter predator consumption estimates of the prey species as "landings" so that the fishing effort data refer to the predator consumption data; 4) use an option in the model to calculate the predator-prey ratio for use in place of the original predator abundance "fishing effort" data; and 5) tune fishing mortality rates for landings (a.k.a. predator consumption) to fishing effort (a.k.a. predator-prey ratio).

Given the predator abundance data κ_y, the model calculates the predator-prey ratio used in place of fishing effort data (E_y) as:

$$E_y = \frac{\kappa_y}{B_y}$$

where B_y is the model's current estimate of total (a.k.a "prey") biomass. Subsequent calculations with E_y and the model's estimates of "fishing mortality" (F_y, really a measure of natural mortality) are exactly as described above for effort data. In using this approach, it is probably advisable to reduce m (the estimate of average mortality in the model) to account for the proportion of natural mortality due to predators included in the calculation. Based on experience to date, natural mortality due to consumption by the suite of predators can be estimated but only if *m* is assumed known.

Initial population age structure

In the KLAMZ model, old and new recruit biomass during the first year (R_1 and $S_1 = B_1 - R_1$) and biomass prior to the first year (B_0) are estimated as log scale parameters. Survival in the year prior to the first year ("year 0") is $\tau_0 = e^{-F_0 - M_1}$ with F_0 chosen to obtain catch C_0 (specified as data) from the estimated biomass B_0. IGRs during year 0 and year 1 are assumed equal ($G_0 = G_1$) in catch calculations.

Biomass in the second year of as series of delay-difference calculations depends on biomass (B_0) and survival (τ_0) in year 0:

$$B_2 = (1+\rho)\,\tau_1\, B_1 - \rho\,\tau_1\,\tau_0\, B_0 + R_2 - \rho\,\tau_1\, J_1\, R_1$$

There is, however, there is no direct linkage between B_0 and escapement biomass ($S_1 = B_1 - R_1$) at the beginning of the first year.

The missing link between B_0, S_1 and B_1 means that the parameter for B_0 tends to be relatively free and unconstrained by the underlying population dynamics model. In some cases, B_0 can be estimated to give good fit to survey and other data, while implying unreasonable initial age composition and surplus production levels. In other cases, B_0 estimates can be unrealistically high or low implying, for example, unreasonably high or low recruitment in the first year of the model (R_1). Problems arise because many different combinations of values for R_1, S_1 and B_0 give similar results in terms of goodness of fit. This issue is common in stock assessment models that use forward simulation calculations because initial age composition is difficult to estimate. It may be exacerbated in delay-difference models because age composition data are not used.

The KLAMZ model uses two constraints to help estimate initial population biomass and initial age structure.13 The first constraint links IGRs for escapement (G^{Old}) in the first years to a subsequent value. The purpose of the constraint is to ensure consistency in average growth rates (and implicit age structure) during the first few years. For example, if IGRs for the first n_G years are constrained14, then the NLL for the penalty is:

$$L_G = 0.5 \sum_{t=1}^{n_G} \left[\frac{\ln\left(G_t^{Old} / G_{n_G+1}^{Old}\right)}{\sigma_G} \right]^2$$

where the standard deviation σ_G is supplied by the user. It is usually possible to use the standard deviation of Q_t^{Old} for later years from a preliminary run to estimate σ_G for the first few years. The constraint on initial IGRs should probably be "soft" and non-binding ($\lambda \approx 1$) because there is substantial natural variation in somatic growth rates due to variation in age composition.

The second constraint links B_0 to S_1 and ensures conservation of mass in population dynamics between years 0 and 1. In other words, the parameter for escapement biomass in year 1 is constrained to match an approximate projection of the biomass in year 0, accounting for growth, and natural and fishing mortality. The constraint is intended to be binding and satisfied exactly (e.g. λ=1000) because incompatible values of S_1 and B_0 are biologically impossible. In calculations:

$$S_1^p = B_0 e^{G_1 - F_0 - M_1}$$

where S_1^p is the projected escapement in year 1 and B_0 is the model's estimate of total biomass in year 0. The instantaneous rates for growth and natural mortality from year 1 (G_1 and M_1) are used in place of G_0 and M_0 because the latter are unavailable. The NLL for the constraint:

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13 Quinn and Deriso (1999) describe another approach attributed to a manuscript by C. Walters.

14 Normally, $n_G \le 2$.

$$L = \left[\ln\left(\frac{S_1^p}{S_1} \right)^2 \right]^2 + \left(S_1^p - S_1 \right)^2$$

uses a log scale sum of squares and an arithmetic sum of squares. The former is effective when S_1 is small while the latter is effective when S_1 is large. Constants and details in calculation of NLL for the constraint are not important because the constraint is binding (e.g. λ=1000).

Equilibrium pristine biomass

It may be useful to constrain the biomass estimate for the first year in a model run towards an estimate of equilibrium pristine biomass if, for example, stock dynamics tend to be stable and catch data are available for the first years of the fishery, or as an alternative to the approach described above for initializing the age structure of the simulated population in the model. Equilibrium pristine biomass $\tilde{B}_0$ is calculated based on the model's estimate of average recruitment and with no fishing mortality (calculations are similar to those described under "Per-recruit modeling" except that average recruitment is assumed in each year).15 The NLL term for the constraint is:

$$L = \ln\left(\frac{\tilde{B}_0}{B_0} \right)^2$$

Pristine equilibrium biomass is used as a hard constraint with a high emphasis factor (λ) so that the variance and constants normally used in NLL calculations are not important.

Estimating natural mortality

As described above, natural mortality calculations involve a parameter for the geometric mean value (m) and time dependent deviations (ϖ_t, which may or may not be turned on). Constraints on natural mortality process errors and natural mortality covariates can be used to help estimate the time dependent deviations and overall trend. The geometric mean natural mortality rate is usually difficult to estimate and best treated as a known constant. However, in the C++ version of the KLAMZ model, $m=e^{\pi}$ (where π is an estimable parameter in the model) and estimates of m can be conditioned on the constraint:

$$L = 0.5\left[\frac{\ln\left(w/w_{Target} \right)}{\sigma_{\varpi}} \right]^2$$

where w_{Target} is a user supplied mean or target value and σ_{ϖ} is a log scale standard deviation. The standard deviation is calculated from an arithmetic scale CV supplied by the user. Upper and lower bounds for m may be specified as well.

Goodness of fit for trend data

Assuming lognormal errors16, the NLL used to measure goodness-of-fit to "survey" data that measure trends in abundance or biomass (or survival, see below) is:

15 Future versions of the KLAMZ model will allow equilibrium initial biomass to be calculated based on other recruitment values and for a user-specified level of F (Butler et al. 2003).

16 Abundance indices with statistical distributions other than log normal may be used as well, but are not currently programmed in the KLAMZ model. For example, Butler et al. (2003) used abundance indices with binomial distributions in a delay-difference model for cowcod rockfish. The next version of KLAMZ will accommodate presence-absence data with binomial distributions.

$$L = 0.5 \sum_{j=1}^{N_v} \left[\frac{\ln\left(I_{v,j} \Big/ \hat{I}_{v,j} \right)}{\sigma_{v,j}} \right]^2$$

where $I_{v,t}$ is an index datum from survey v, hats "^" denote model estimates, $\sigma_{v,j}$ is a log scale standard error (see below), and N_v is the number of observations. There are two approaches to calculating standard errors for log normal abundance index data in KLAMZ and it is possible to use different approaches for different types of abundance index data in the same model (see below).

Standard errors for goodness of fit

In the first approach, all observations for one type of abundance index share the same standard error, which is calculated based on overall goodness of fit. This approach implicitly estimates the standard error based on goodness of fit, along with the rest of the parameters in the model (see "NLL kernels" above).

In the second approach, each observation has a potentially unique standard error that is calculated based on its CV. The second approach calculates log scale standard errors from arithmetic CVs supplied as data by the user (Jacobson et al. 1994):

$$\sigma_{v,t} = \sqrt{\ln\left(1 + CV_{v,t}^2\right)}$$

Arithmetic CV's are usually available for abundance data. It may be convenient to use $CV_{v,t}$=1.31 to get $\sigma_{v,t}$=1.

There are advantages and disadvantages to both approaches. CV's carry information about the relative precision of abundance index observations. However, CV's usually overstate the precision of data as a measure of fish abundance17 and may be misleading in comparing the precision of one sort of data to another as a measure of trends in abundance (e.g. in contrasting standardized LPUE that measure fishing success, but not abundance, precisely with survey data that measure trends in fish abundance directly, but not precisely). Standard errors estimated implicitly are often larger and more realistic, but assume that all observations in the same survey are equally reliable.

Predicted values for abundance indices

Predicted values for abundance indices are calculated:

$$\hat{I}_{v,t} = Q_v A_{v,t}$$

where Q_v is a survey scaling parameter (constant here but see below) that converts units of biomass to units of the abundance index. $A_{v,t}$ is available biomass at the time of the survey.

In the simplest case, available biomass is:

$$A_{v,t} = s_{v,New} R_t e^{-X_t^{New} \Delta_{v,t}} + s_{v,Old} S_t e^{-X_t^{Old} \Delta_{v,t}}$$

where $s_{v,New}$ and $s_{v,Old}$ are survey selectivity parameters for new recruits (R_t) and old recruits (S_t); $X_t^{New} = G_t^{New} - F_t - M_t$ and $X_t^{Old} = G_t^{Old} - F_t - M_t$; $j_{v,t}$ is the Julian date at the time of the survey, and $\Delta_{v,t}=j_{v,t}/365$ is the fraction of the year elapsed at the time of the survey.

17 The relationship between data and fish populations is affected by factors (process errors) that are not accounted for in CV calculations.

Survey selectivity parameter values ($s_{v,New}$ and $s_{v,Old}$) are specified by the user and must be set between zero and one. For example, a survey for new recruits would have $s_{v,New}$=1 and $s_{v,Old}$=0. A survey that measured abundance of the entire stock would have $s_{v,New}$=1 and $s_{v,Old}$=1.

Terms involving $\Delta_{v,t}$ are used to project beginning of year biomass forward to the time of the survey, making adjustments for mortality and somatic growth.18 As described below, available biomass $A_{v,t}$ is adjusted further for nonlinear surveys, surveys with covariates and surveys with time variable $Q_{v,t}$.

Scaling parameters (Q) for log normal abundance data

Scaling parameters for surveys with lognormal statistical errors were computed using the maximum likelihood estimator:

$$Q_v = e^{\frac{\sum_{i=1}^{N_v}\left[\ln\left(\frac{I_{v,i}}{A_{v,i}}\right) \Big/ \sigma^2_{v,j}\right]}{\sum_{j=1}^{N_j}\left(1 \big/ \sigma^2_{v,j}\right)}}$$

where N_v is the number of observations with individual weights greater than zero. The closed form maximum likelihood estimator gives the same answer as if scaling parameters are estimated as free parameters in the assessment model assuming lognormal survey measurement errors.

Survey covariates

Survey scaling parameters may vary over time based on covariates in the KLAMZ model. The survey scaling parameter that measures the relationship between available biomass and survey data becomes time dependent:

$$\hat{I}_{v,t} = Q_{v,t} A_{v,t}$$

and

$$Q_{v,t} = Q_v e^{\sum_{r=1}^{n_v} d_{r,t}\theta_r}$$

with n_v covariates for the survey and parameters θ_r estimated in the model. Covariate effects and available biomass are multiplied to compute an adjusted available biomass:

$$A'_{v,t} = A_{v,t} e^{\sum_{r=1}^{n_v} d_{r,t}\theta_r}$$

The adjusted available biomass $A'_{v,t}$ is used instead of the original value $A_{v,t}$ in the closed form maximum likelihood estimator described above.

Covariates might include, for example, a dummy variable that represents changes in survey bottom trawl doors or a continuous variable like average temperature data if environmental factors affect distribution and catchability of fish schools. Dummy variables are usually either 0 or 1, depending on whether the effect is present in a particular year. With dummy variables, Q_v is the value of the survey scaling parameter with no intervention ($d_{r,t}$=0).

For ease in interpretation of parameter estimates for continuous covariates (e.g. temperature data), it is useful to center covariate data around the mean:

$$d_{r,t} = d'_{r,t} - \overline{d'_r}$$

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18 It may be important to project biomass forward if an absolute estimate of biomass is available (e.g. from a hydroacoustic or daily egg production survey), if fishing mortality rates or high or if the timing of the survey varies considerably from year to year.

where $d'_{r,t}$ is the original covariate. When covariates are continuous and mean-centered, Q_v is the value of the survey scaling parameter under average conditions ($d_{r,t}$=0) and units for the covariate parameter are easy to interpret (for example, units for the parameter are 1/ °C if the covariate is mean centered temperature in °C).

It is possible to use a survey covariate to adjust for differences in relative stock size from year to year due to changes in the timing of a survey. However, this adjustment may be made more precisely by letting the model calculate $\Delta_{v,t}$ as described above, based on the actual timing data for the survey during each year.

Nonlinear abundance indices

With nonlinear abundance indices, and following Methot (1990), the survey scaling parameter is a function of available biomass:

$$Q_{v,t} = Q_v A_{v,t}^{\Gamma}$$

so that:

$$\hat{I}_{v,t} = \left(Q_v A_{v,t}^{\Gamma}\right) A_{v,t}$$

Substituting $e^{\gamma} = \Gamma + 1$ gives the equivalent expression:

$$\hat{I}_{v,t} = Q_v A_{v,t}^{e^{\gamma}}$$

where γ is a parameter estimated by the model and the survey scaling parameter is no longer time dependent. In calculations with nonlinear abundance indices, the adjusted available biomass:

$$A'_{v,t} = A_{v,t}^{e^{\gamma}}$$

is computed first and used in the closed form maximum likelihood estimator described above to calculate the survey scaling parameter. In cases where survey covariates are also applied to a nonlinear index, the adjustment for nonlinearity is carried out first.

Survey Q process errors

The C++ version of the KLAMZ model can be used to allow survey scaling parameters to change in a controlled fashion from year to year (NEFSC 2002):

$$Q_{v,t} = Q_v e^{\varepsilon_{v,t}}$$

where the deviations $\varepsilon_{v,t}$ are constrained to average zero. Variation in survey Q values is controlled by the NLL penalty:

$$L = 0.5 \sum_{j=1}^{N_v} \left[\frac{\varepsilon_{v,j}}{\sigma_v} \right]^2$$

where the log scale standard deviation σ_v based on an arithmetic CV supplied by the user (e.g. see NEFSC 2002). In practice, the user increases or decreases the amount of variability in Q by decreasing or increasing the assumed CV.

Survival ratios as surveys

In the C++ version of KLAMZ, it is possible to use time series of survival data as "surveys". For example, an index of survival might be calculated using survey data and the Heinke method (Ricker 1975) as:

$$A_t = \frac{I_{k+1,t+1}}{I_{k,t}}$$

so that the time series of A_t estimates are data that may potentially contain information about scale or trends in survival. Predicted values for an a survival index are calculated:

$$\hat{A}_t = e^{-Z_t}$$

After predicted values are calculated, survival ratio data are treated in the same way as abundance data (in particular, measurement errors are assumed to be lognormal). Selectivity parameters are ignored for survival data but all other features (e.g. covariates, nonlinear scaling relationships and constraints on Q) are available.

Recruitment models

Recruitment parameters in KLAMZ may be freely estimated or estimated around an internal recruitment model, possibly involving spawning biomass. An internally estimated recruitment model can be used to reduce variability in recruitment estimates (often necessary if data are limited), to summarize stock-recruit relationships, or to make use of information about recruitment in similar stocks. There are four types of internally estimated recruitment models in KLAMZ: 1) random (white noise) variation around a constant or time dependent mean modeled as a step function; 2) random walk (autocorrelated) variation around a constant or time dependent mean modeled as a step function; 3) random variation around a Beverton-Holt recruitment model; and 4) random variation around a Ricker recruitment model. The user must specify a type of recruitment model but the model is not active unless the likelihood component for the recruitment model is turned on ($\lambda > 0$).

The first step in recruit modeling is to calculate the expected log recruitment level $E[ln(R_t)]$ given the recruitment model. For random variation around a constant mean, the expected log recruitment level is the log geometric mean recruitment:

$$E\left[\ln\left(R_t\right)\right] = \sum_{j=1}^{N} \ln\left(R_j\right) \Big/ N$$

For a random walk around a constant mean recruitment, the expected log recruitment level is the logarithm of recruitment during the previous year:

$$E\left[\ln\left(R_t\right)\right] = \ln\left(R_{t-1}\right)$$

with no constraint on recruitment during the first year R_1.

For the Beverton-Holt recruitment model, the expected log recruitment level is:

$$E\left[\ln\left(R_t\right)\right] = \ln\left[e^a T_{t-\ell} \Big/ \left(e^b + T_{t-\ell}\right)\right]$$

where $a=e^\alpha$ and $b=e^\beta$, the parameters α and β are estimated in the model, T_t is spawning biomass, and { is the lag between spawning and recruitment. Spawner-recruit parameters are estimated as log transformed values (e^α and e^β) to enhance model stability and ensure the correct sign of values used in calculations. Spawning biomass is:

$$T_t = m_{new} R_t + m_{old} S_t$$

where m_{new} and m_{old} are maturity parameters for new and old recruits specified by the user. For the Ricker recruitment model, the expected log recruitment level is:

$$E\left[\ln\left(R_t\right)\right] = \ln\left(S_{t-\ell} e^{a - bS_{t-\ell}}\right)$$

where $a=e^\alpha$ and $b=e^\beta$, and the parameters α and β are estimated in the model.

Given the expected log recruitment level, log scale residuals for the recruitment model are calculated:

$$r_t = \ln\left(R_t\right) - E\left[\ln\left(R_t\right)\right]$$

Assuming that residuals are log normal, the NLL for recruitment residuals is:

$$L = \sum_{t=t_{first}}^{N} w_t \left[\ln\left(\sigma_r\right) + 0.5 \left(r_t \Big/ \sigma_r \right)^2 \right]$$

where λ_t is an instance-specific weight usually set equal one. The additional term in the NLL [$ln(\sigma_r)$] is necessary because the variance σ_r^2 is estimated internally, rather than specified by the user.

The log scale variance for residuals is calculated using the maximum likelihood estimator:

$$\sigma_r^2 = \frac{\sum_{j=t_{first}}^{N} r_j}{N}$$

where N is the number of residuals. For the recruitment model with constant variation around a mean value, t_{first}=1. For the random walk recruitment model, t_{first}=2. For the Beverton-Holt and Ricker models, t_{first}= $\ell + 1$ and the recruit model imposes no constraint on variability of recruitment during years 1 to ℓ (see below). The biased maximum likelihood estimate for σ^2 (with N in the divisor instead of the degrees of freedom) is used because actual degrees of freedom are unknown. The variance term σ^2 is calculated explicitly and stored because it is used below.

Constraining the first few recruitments

It may be useful to constrain the first ℓ years of recruitments when using either the Beverton-Holt or Ricker models if the unconstrained estimates for early years are erratic. In the KLAMZ model, this constraint is calculated:

$$NLL = \sum_{t=1}^{t_{first}-1} w_t \left\{ \ln(\sigma_r + 0.5\left[\frac{\ln\left(R_t / E\left(R_{t_{first}}\right)\right)}{\sigma_r}\right]^2 \right\}$$

where t_{first} is the first year for which expected recruitment $E(R_t)$ can be calculated with the spawner-recruit model. In effect, recruitments that not included in spawner-recruit calculations are constrained towards the first spawner-recruit prediction. The standard deviation is the same as used in calculating the NLL for the recruitment model.

<u>Prior information about the absolute value abundance index scaling parameters (Q)</u>

A constraint on the absolute value one or more scaling parameters (Q_v) for abundance or survival indices may be useful if prior information is available (e.g. NEFSC 2000; NEFSC 2001; NEFSC 2002). In the Excel version, it is easy to program these (and other) constraints in an *ad-hoc* fashion as they are needed. In the AD Model Builder version, log normal and beta distributions are preprogrammed for use in specifying prior information about Q_v for any abundance or survival index.

The user must specify which surveys have prior distributions, minimum and maximum legal bounds (q_{min} and q_{max}), the arithmetic mean $(\bar{q})$ and the arithmetic CV for the prior the distribution. Goodness of fit for Q_v values outside the bounds (q_{min}, q_{max}) are calculated:

$$L = \begin{vmatrix} 10000\,(Q_v - q_{\max})^2 \; if \; Q_v \geq q_{\max} \\ 10000\,(q_{\min} - Q_v)^2 \; if \; Q_v \leq q_{\min} \end{vmatrix}$$

Goodness of fit for Q_v values inside the legal bounds depend on whether the distribution of potential values is log normal or follows a beta distribution.

Lognormal case

Goodness of fit for lognormal Q_v values within legal bounds is:

$$L = 0.5\left[\frac{\ln(Q_v) - \tau}{\varphi}\right]^2$$

where the log scale standard deviation $\varphi = \sqrt{\ln(1 + CV)}$ and $\tau = \ln(\bar{q}) - \frac{\varphi^2}{2}$ is the mean of the corresponding log normal distribution.

Beta distribution case

The first step in calculation goodness of fit for Q_v values with beta distributions is to calculate the mean and variance of the corresponding "standardized" beta distribution:

$$\bar{q}' = \frac{\bar{q} - q_{\min}}{D}$$

and

$$Var(q') = \left(\frac{\bar{q}\ CV}{D} \right)^2$$

where the range of the standardized beta distribution is $D=q_{max}-q_{min}$. Equating the mean and variance to the estimators for the mean and variance for the standardized beta distribution (the "method of moments") gives the simultaneous equations:

$$\bar{q}' = \frac{a}{a+b}$$

and

$$Var(q') = \frac{ab}{(a+b)^2 (a+b+1)}$$

where a and b are parameters of the standardized beta distribution.19 Solving the simultaneous equations gives:

$$b = \frac{(\bar{q}'-1)\left[Var(q') + (\bar{q}'-1)\bar{q}'\right]}{Var(q')}$$

and:

$$a = \frac{b\bar{q}'}{1-\bar{q}'}$$

Goodness of fit for beta Q_v values within legal bounds is calculated with the NLL:

$$L = (a-1)\ln(Q'_v) + (b-1)\ln(1-Q'_v)$$

where $Q'_v = Q_v / (Q_v - q_{\min})$ is the standardized value of the survey scaling parameter Q_v.

<u>Prior information about relative abundance index scaling parameters (*Q-ratios*)</u>

Constraints on "Q-ratios" can be used in fitting models if some information about the relative values of scaling parameters for two abundance indices is available. For example, ASMFC (2001, p. 46-47) assumed that the relative scaling parameters for recruit and post-recruit lobsters taken in the same survey was either 0.5 or 1. If both indices are from the same survey cruise (e.g. one index for new recruits and one index for old recruits in the same survey), then assumptions about q-ratios are analogous to assumptions about the average selectivity of the survey of the survey for new and old recruits.

Q-ratio constraints tend to stabilize and have strong effects on model estimates. ASMFC (2001, p. 274) found, for example, that goodness of fit to survey data, abundance and fishing mortality estimates for lobster changed dramatically over a range of assumed q-ratio values.

To use q-ratio information in the KLAMZ model, the user must identify two surveys, a target value for the ratio of their Q values, and a CV for differences between the models estimated q-ratio and the target value. For example, if the user believes that the scaling parameters for abundance index 1 and abundance index 3 is 0.5, with a CV=0.25 for uncertainty in the prior information then the model's estimate of the q-ratio is $\rho=Q_1/Q_3$. The goodness of fit calculation is:

$$L = 0.5\left(\frac{\ln(\rho/\tau)}{\sigma} \right)^2$$

where τ is the target value and the log scale standard deviation σ is calculated from the arithmetic CV supplied by the user.

Normally, a single q-ratio constraint would be used for the ratio of new and old recruits taken during the

19 If x has a standardized beta distribution with parameters a and b, then the probability of x is

$$P(x) = \frac{x^{a-1}(1-x)^{b-1}}{\Gamma(a,b)}.$$

same survey operation. However, in KLAMZ any number of q-ratio constraints can be used simultaneously and the scaling parameters can be for any two indices in the model.

Surplus production modeling

Surplus production models can be fit internally to biomass and surplus production estimates in the model (Jacobson et al. 2002). Models fit internally can be used to constrain estimates of biomass and recruitment, to summarize results in terms of surplus production, or as a source of information in tuning the model. The NLL for goodness of fit assumes normally distributed process errors in the surplus production process:

$$L = 0.5 \sum_{j=1}^{N_P} \left(\frac{\tilde{P}_j - P_j}{\sigma} \right)^2$$

where N_p is the number of surplus production estimates (number of years less one), $\tilde{P}_t$ is a predicted value from the surplus production curve, P_t is the assessment model estimate, and the standard deviation σ is supplied by the user based, for example, on preliminary variances for surplus production estimates.[20] Either the symmetrical Schaefer (1957) or asymmetric Fox (1970) surplus production curve may be used to calculate $\tilde{P}_t$ (Quinn and Deriso 1999).

It may be important to use a surplus production curve that is compatible with recruitment patterns or assumptions about the underlying spawner-recruit relationship. More research is required, but the asymmetric shape of the Fox surplus production curve appears reasonably compatible with the assumption that recruitment follows a Beverton-Holt spawner-recruit curve (Mohn and Black 1998). In contrast, the symmetric Schaefer surplus production model appears reasonably compatible with the assumption that recruitment follows a Ricker spawner-recruit curve.

The Schaefer model has two log transformed parameters that are estimated in KLAMZ:

$$\tilde{P}_t = e^{\alpha} B_t - e^{\beta} B_t^2$$

The Fox model also has two log transformed parameters:

$$\tilde{P}_t = -e\left(e^{e^{\alpha}}\right) \frac{B_t}{e^{\beta}} \log\left(\frac{B_t}{e^{\beta}}\right)$$

See Quinn and Deriso (1999) for formulas used to calculate reference points (F_{MSY}, B_{MSY}, MSY, and K) for both surplus production models.

Catch/biomass

Forward simulation models like KLAMZ may tend to estimate absurdly high fishing mortality rates, particularly if data are limited. The likelihood constraint used to prevent this potential problem is:

$$L = 0.5 \sum_{t=0}^{N} \left(d_t^2 + q^2 \right)$$

where:

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20 Variances in NLL for surplus production-biomass models are a subject of ongoing research. The advantage in assuming normal errors is that negative production values (which occur in many stocks, e.g. Jacobson et al. 2001) are accommodated. In addition, production models can be fit easily by linear regression of P_t on B_t and B_t^2 with no intercept term. However, variance of production estimate residuals increases with predicted surplus production. Therefore, the current approach to fitting production curves in KLAMZ is not completely satisfactory.

$$d_t = \begin{vmatrix} Ft - \Phi \; if \; Ft > \Phi \\ 0 \; otherwise \end{vmatrix}$$

and
with the threshold value κ normally set by the user to about 0.95. Values for κ can be linked to maximum F values using the modified catch equation described above. For example, to use a maximum fishing mortality rate of about $F \approx 4$ with M=0.2 and G=0.1 (maximum X=4+0.2-0.1=4.1), set $\kappa \approx F/X(1-e^{-X})$=4 / 4.1 (1-$e^{-4}$)=0.96.

Uncertainty

The AD Model Builder version of the KLAMZ model automatically calculates variances for parameters and quantities of interest (e.g. R_t, F_t, B_t, F_{MSY}, B_{MSY}, $\overline{F}_{\mathrm{Re}\,cent}$, $\overline{B}_{\mathrm{Re}\,cent}$, $\overline{F}_{\mathrm{Re}\,cent} / F_{MSY}$, $\overline{B}_{\mathrm{Re}\,cent} / B_{MSY}$, etc.) by the delta method using exact derivatives. If the objective function is the log of a proper posterior distribution, then Markov Chain Monte Carlo (MCMC) techniques implemented in AD Model Builder libraries can be used estimate posterior distributions representing uncertainty in the same parameters and quantities.21

Bootstrapping

A FORTRAN program called BootADM can be used to bootstrap survey and survival index data in the KLAMZ model. Based on output files from a "basecase" model run, BootADM extracts standardized residuals:

$$r_{v,j} = \frac{\ln\left(I_{v,j} \Big/ \hat{I}_{v,j} \right)}{\sigma_{v,j}}$$

along with log scale standard deviations ($\sigma_{v,j}$, originally from survey CV's or estimated from goodness of fit), and predicted values $\left(\hat{I}_{v,j}\right)$ for all active abundance and survival observations. The original standardized residuals are pooled and then resampled (with replacement) to form new sets of bootstrapped survey "data":

$${}^{x}I_{v,j} = \hat{I}_{v,j} e^{r\sigma_{v,j}}$$

where r is a resampled residual. Residuals for abundance and survival data are combined in bootstrap calculations. BootADM builds new KLAMZ data files and runs the KLAMZ model repetitively, collecting the bootstrapped parameter and other estimates at each iteration and writing them to a comma separated text file that can be processed in Excel to calculate bootstrap variances, confidence intervals, bias estimates, etc. for all parameters and quantities of interest (Efron 1982).

Projections

Stochastic projections can be carried out using another FORTRAN program called SPROJDDF based on bootstrap output from BootADM. Basically, bootstrap estimates of biomass, recruitment, spawning biomass, natural and fishing mortality during the terminal years are used with recruit model parameters from each bootstrap run to start and carryout projections.22 Given a user-specified level of catch or fishing mortality, the delay-difference equation is used to project stock status for a user-specified number of years. Recruitment during each projected year is based on simulated spawning biomass, log normal random numbers, and spawner-recruit parameters (including the residual variance) estimated in the bootstrap run. This approach is similar to carrying out projections based on parameters and state variables sampled from a posterior distribution for the basecase model fit. It differs from most current approaches because the spawner-recruit parameters vary from projection to projection.

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21 MCMC calculations are not available in the current version because objective function calculations use concentrated likelihood formulas. However, the C++ version of KLAMZ is programmed in other respects to accommodate Bayesian estimation.
22 At present, only Beverton-Holt recruitment calculations are available in SPROJDDF.

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Appendix A5: KLAMZ model results

KLAMZ modeling

The KLAMZ model for the entire surfclam stock during was the main modeling approach and primary basis for providing management advice in the last assessment (NEFSC 2010). KLAMZ model results are provided here to build a bridge between the previous assessment and the current one. KLAMZ results are also provided for the Northern and Southern areas.

The KLAMZ assessment model is based on the Deriso-Schnute delay-difference equation (Deriso 1980; Schnute 1985; see complete technical documentation in Appendix A4). The delay-difference equation is a relatively simple and implicitly age structured approach. It gives the same results as explicitly age-structured models (e.g. Leslie matrix model) if fishery selectivity is "knife-edged", if somatic growth follows the von Bertalanffy equation, and if natural mortality is the same for all age groups in each year. Natural and fishing mortality rates, growth parameters and recruitment may change from year to year.

There are two age or size groups in KLAMZ, "new" and "old" recruits that, together, comprise the whole stock. New recruits are individuals that recruited at the beginning of the current year. Old recruits are all older individuals in the stock that recruited at the beginning of previous years.

KLAMZ delay-difference models in this assessment were for surfclam biomass dynamics during 1981-2011 and were generally similar to models used in the last surfclam assessment (NEFSC 2010). The first year with survey data was 1982, however, the model has an estimable parameter for biomass in 1981 that defines the initial age structure. Landings data are available for earlier years. A number of changes, primarily to input data, for this assessment are described below under "Building a bridge". As in the last assessment, the natural mortality rate is $M=0.15$ y^{-1} (Appendix A4).

Growth patterns were assumed to vary over time in all models because of recent slow growth in the DMV and NJ regions and because of changes in the distribution of the stock among regions which have different SLMWT and von Bertalanffy growth patterns. In the KLAMZ model, the growth parameter $J_t=w_{t-1k-1}/w_{t,k}$ (where $w_{t,k}$ is the mean body weight of a surfclam at the age of recruitment k in year t) may vary from year to year. The growth parameter J_t represents the combined effects of the traditional von Bertalanffy growth parameters W_∞ and t_0. This approach was adequate for surfclams because much of the variation in growth appeared to be in maximum size W_∞ (Table A16 Assessment report).

Model configuration

NEFSC clam survey data in the KLAMZ model were for new and old recruits. Surveys were assumed to occur in the middle of the year because the NEFSC clam survey is carried out during late May-early July. As in the previous assessment, survey data used in the KLAMZ model were trends, after holes (unsampled survey strata in some years) were filled to the extent possible by borrowing data from the previous and successive surveys. Some years were not used in whole stock or Northern area modeling because GBK was undersampled (Figure 1). For example, GBK was not sampled at all in 2005.

Survey trend data (stratified mean kg/tow) for surfclams 120-129 mm SL were assumed to track trends in biomass of new recruits. Survey data for surfclams 130+ mm were assumed to track trends in the entire stock (old recruits).

Following NEFSC (2009), swept area biomass estimates were included in the assessment model to measure scale, but not trends, in biomass. Swept area biomass estimates were not efficiency corrected in this case because the prior on survey efficiency (see TOR 2) was intended to carry forward model uncertainty in scale. Goodness of fit to the swept area biomass data was given nil weight in the overall objective function. However, the likelihood of the estimated scaling parameter for swept area biomass was calculated based on a log normal prior distribution with mean 0.234 and arithmetic CV = 1.32 and the likelihood was added to the objective function used in fitting the model. The CV was estimated by bootstrapping all available data on survey dredge efficiency (see TOR 2). The CV is relatively broad and the prior information had a little effect in determining the overall scale of surfclam biomass and fishing mortality estimates. Experience has shown that surfclam stock assessment data, aside from the swept are area biomass estimates, are uninformative about the overall scale of biomass but do provide information about trends. Thus, the model tended to be uncertain regarding overall scale, for which there was limited data beyond the somewhat uninformative (high CV) prior distribution on survey dredge efficiency.

Following NEFSC (2003) surfclam recruits were estimated in the KLAMZ model as a random walk with steps constrained by a variance parameter. A smooth, random walk process is probably not ideal from a biological perspective because of the evidence in survey age composition data for strong year classes, but the approach was necessary because of the lack of annual recruitment data. The random walk approach keeps the recruitment estimate in year *t* at the same level as in year *t-1*, unless there is a good reason, in terms of goodness of fit, to change it. For surfclams in the KLAMZ model, the random walk approach helped avoid excessive variation in recruitment, enhanced model convergence, and ensured that some recruitment was estimated for each year.

In modeling surfclam population dynamics with random walk recruitment, it is important to tune the "random walk recruitment variance" σ_R^2 which measures variability in the size of successive steps taken during the random walk (i.e. variance in [ln(R_1/R_2), ln(R_2/R_3), ln(R_3/R_4), etc.], where R_t is the recruitment estimate for year *t*). As σ_R^2 approaches zero, recruitment estimates become smooth and tend towards a constant value with no changes from year to year. As σ_R^2 becomes large, estimated recruitments will change randomly and more widely from one year to next.

Following NEFSC (2007), initial KLAMZ model runs assumed high CV for steps in the random walk. The assumed CV was gradually decreased in subsequent runs until the model was just able to fit the survey data without pattern in residuals and the model was able to fully converge (the Hessian matrix was invertible). In addition, the CV for fit to the survey data (residual CV) was compared to CV for the actual survey data to determine if the model was fitting the survey data more closely than should be expected based on the precision of the survey data (implying that σ_R^2 was too large). Finally, it was determined that the fit to the "old" recruit time series should be better than the fit to the new recruit time series as the older recruits were based on a broader set of size classes and thus more data. The goal was basically to find the model that would adequately explain the survey data for surfclams, but not over fit the new recruit time series.

Recruitment estimates for surfclam from the KLAMZ model are complicated to interpret because of the constraints on variability and limited survey data. Under these conditions, recruitment estimates for surfclam from the KLAMZ model should probably be regarded as "nuisance" parameters of less interest than biomass and fishing mortality estimates. Recruitment estimates for surfclams at best reflect long term average trends. However, recruitment estimates in the KLAMZ model are aliased with model misspecification, survey noise, survey year effects, natural mortality and variability in growth.

Results-whole stock

The KLAMZ model fit survey biomass trend data reasonably well (Figure 2). The model fit the whole stock survey data index better than the index for new recruits, as expected based on the CV for the two sets of survey data (CV for the recruit index are higher).

The survey scaling parameter for efficiency corrected swept area biomass was Q=0.16, which is close to the mode of the prior distribution of survey dredge efficiency. This indicates that the trend data, landings and model estimates did not provide sufficient information on scale to shift the model away from the relatively uninformative prior information about Q for swept area biomass estimates.

Model results (Figure 3 - 4) suggest that surplus production was high before the late 1990's and steadily declined afterwards to negative levels during 2001-2011 as somatic growth and recruitment rates declined. Biomass increased until the late 1990s when surplus production was less than catch.

Bootstrap and delta method CV for biomass, and recruitment estimates were < 25% indicating that estimates were reasonably precise (Table 1). The bootstrap CV for fishing mortality were high because the denominator, the estimated fishing mortality values, were often close to zero. Delta method CV are probably the better measure of uncertainty in this case.

Internal retrospective analysis

Retrospective analyses were carried out with the base case KLAMZ model for terminal years 2000-2011 (Figure 5). There was little evidence of a retrospective problem in either biomass or fishing mortality estimates. The model tends to fluctuate somewhat in scale because the scale of the model is uncertain, but the trend is consistent through time. Changes in scale tended to occur when data from an additional NEFSC clam survey (as in the case of 2002, 2008 and 2011) was dropped.

Historical retrospective analysis

Biomass and fishing mortality estimates from surfclam stock assessments carried out since 1998 were compared to determine the stability of stock estimates used to provide management advice (Figure 6). The scale of the model fit is considerably higher than in past assessments. This is primarily due to changes in the way survey efficiency was estimated and the increased variance in the prior distribution for survey *Q*. The most important aspect of the historical retrospective analysis is the substantial differences between base case biomass and fishing mortality estimates and estimates from the previous assessment. The factors responsible for these changes are explained below.

Performance of historical projections

The current model differed from historical projections. Comparisons in trend were used because the scale of the model in the last assessment was much lower (Figure 6). In the last assessment the projected biomass in 2011 was approximately 6% lower than biomass in 2008. Using the current whole stock KLAMZ model, biomass in 2011 was approximately 14% lower than biomass in 2008 (Table 2). The discrepancy can be explained by differences in estimated trend between the models, caused by differences in the fit to the survey data (see below).

Building a bridge

Differences between estimates in the base case model in this assessment and the last assessment due to modifications to data and modeling procedures. These are discussed below, one step at a time (Figure 7). The most important factors contributing to differences between the base case model biomass estimates in this assessment and estimates in the previous assessment are: additional variance in the prior distribution for survey *Q* (Step 3), and additional variance allowed in the fit to the recruit time series (Step 2, Step 13).

Step 1 was to run the KLAMZ model using updated data from the last assessment to determine if any new bugs had crept into the model code. The model was able to estimate parameters, but produced steep gradients and did not converge. Step 2 was to allow more freedom in the variance of the random walk recruitment parameter, σ_R^2, which allowed a better fit to the survey data for both old and new recruits. This step reduced the magnitude of the gradients, but still did not produce an invertible hessian matrix. Step 3 was to incorporate the new prior distribution for survey *Q*, which increased the variance in the prior by an order of magnitude from the last assessment. Step 4 was to include the new selectivity estimates for the survey dredge. The fifth step was to incorporate new SLMWT relationships. Step 6 was to add the updated growth estimates. The model converged for the first time after this step. The seventh step was to decouple the surveys (in previous estimates there was overlap in size classes between the old and new recruits). The eighth step was to include discards in the fishery data being used (a correction to an oversight). The ninth step was to remove data from 1983 from the whole stock model due to poor coverage on GBK. Step 10 was to incorporate changes in sensor data criteria used to identify and discard "bad" survey tows for use in estimating efficiency corrected swept area biomass. The eleventh step was to fix a bug in the routine to borrow data from adjacent years to fill holes in the survey time series. Step 12 was to fix a bug in the growth estimates added in step 6. Finally step 13 was to adjust the σ_R^2 parameter to minimize the overall Likelihood function. Convergence was generally tenuous throughout this process. The model was sensitive to starting conditions and generally produced large gradients even when the hessian matrix was invertible.

Results-Southern Area

The KLAMZ model for the southern area (SVA to SNE) incorporated all of the data available. All survey years were included for new (120 – 129 mm SL) and old (130+ mm SL) recruits. Swept area biomass for all years in which dredge sensors were deployed (1997 and after; Figure 8) were included as well. Catch data between 1982 and 2011 were used.

Other model parameters were selected according to the methodology established in the whole stock model. Growth parameters and juvenile ratios (see above) were calculated for the appropriate subset of the data for the whole stock (animals from SVA to SNE). The σ_R^2 parameter (see above) was chosen to minimize a concentrated Likelihood function that ignored the recruitment model component. The recruitment model component is always minimized by a σ_R^2 equal to zero because it prefers a recruitment model with fewer parameters (see Appendix A4).

Changing the σ_R^2 parameter had a substantial affect on the overall model (Figure 9). The trend of the model fit was relatively unaffected, but the scale changed by as much as a factor of three depending on the value of σ_R^2 chosen.

The model fit the survey data reasonably well (Figure 10). Trends in the overall fit were similar to the fit for the whole stock, indicating that the population biomass peaked in the late 1990's. The southern area, however, indicates a steeper decline since then (Figure 11).

Surplus production (Figure 12) was positive until the mid 1990's and has been negative since then, until 2011. The upward trend in surplus production over the last six years has been driven by strong recruitment.

The scale parameter for the KLAMZ model, survey *Q*, was 0.55. This value is considerably higher than the survey *Q* estimated for the whole stock (0.16). The discrepancy is a result of uncertainty in our extra-model estimates of survey dredge efficiency (see above) and is reflected in the prior distribution which has a CV of 134%. The KLAMZ model is therefore given very little information about scale and that uncertainty is evident in the trouble KLAMZ has in establishing a consistent scale.

Bootstrap runs (n=500) for the southern area KLAMZ model runs were fairly consistent though there were a few extreme outliers (Figure 13). This is reflected in the bootstrap CV which were generally high (Table 3) and driven by outliers which tended to be unconverged cases (~3%). Delta method CV were generally below 20%.

Internal Retrospective

Retrospective analysis indicates a shift in scale, but not trend, as survey years are removed from the model (Figure 14). The model tends to fluctuate somewhat in scale because the scale of the model is uncertain, but the trend is consistent through time. Changes in scale tended to occur when data from an additional NEFSC clam survey (as in the case of 2002, 2008 and 2011) were dropped.

Results-Northern Area

The KLAMZ model for the northern area (GBK) incorporated a subset of the data available. There were some years where coverage on GBK was poor (1982, 1983) and other years where GBK was not sampled (2005). Swept area biomass for all years in which dredge sensors were deployed and GBK was sampled (1997 and after, excluding 2005; Figure 15) were included as well. Catch data was sparse, as GBK was not fished for 20 years between 1989 and 2008.

Other model parameters were selected according to the methodology established in the whole stock model. Growth parameters and juvenile ratios were calculated for the appropriate subset of the data for the whole stock (animals from GBK). The σ_R^2 parameter (see above) was chosen to minimize a concentrated likelihood function, that ignored the recruitment model component. The recruitment model component is minimized by a σ_R^2 equal to zero, because it prefers a recruitment model with fewer parameters (see Appendix A4). This choice could not be made naively however, as it is possible to overfit the recruitment index at the expense of other data. In this case the minimum of the concentrated likelihood occurred at $\ln(\sigma_R^2) = -4$, which would have resulted in the goodness of fit to the recruitment time series being less than the goodness of fit implied by the CV of the index itself. The σ_R^2 parameter was gradually increased until the goodness of fit to the index was greater than the goodness of fit implied by the survey CV ($\ln(\sigma_R^2) = -4.65$; Figure 16). Changing the σ_R^2 parameter had little effect on the overall model (Figure 17).

The model fit the survey data reasonably well (Figure 16). Based on the fit to the survey data, the northern area has been growing since the cessation of fishing there in 1989. The upward trend in growth seems to be tapering off and has been essentially flat for approximately the last 5 years (Figure 18).

Surplus production (Figure 19) was positive from the late 1980's until 2010. The decline in surplus production is probably due to declining recruitment since 1995 (Figure 19).

The scale parameter for the KLAMZ model, survey *Q*, which is analogous to survey dredge efficiency in efficiency corrected swept are biomass calculations was 0.14. This value was comparable to the survey *Q* estimated for the whole stock (0.16). The estimated Q was close to the mean of the prior distribution and indicated that the data provided to the KLAMZ model for the Northern area probably provided very little information about scale. The prior distribution we used was highly uninformative and (CV = 134% see TOR 2 above) and was not likely to influence the estimate of survey Q very much in the presence of data that informed scale. The fact the estimated survey Q did not differ from mean of the prior probably means that the data were not informative regarding scale.

Bootstrap runs (n=500) for the Northern area KLAMZ model runs were fairly consistent (Figure 20). This is reflected in the bootstrap CV which were generally tight (Table 4). Delta method CV were generally very high (~100%). The discrepancy between delta method CV based on the Hessian matrix and the bootstrap CV is probably due to differences between the two methods. The delta method uncertainty reveals a flat likelihood and thus a wide CV in the area immediately around the converged solution. If however the "flatness" of the likelihood surface is confined to a relatively small parameter space, the bootstrap solutions might all arrive at nearly the same solution and thus produce a relatively narrow CV. Some evidence for this is provided by the high rate of convergence in the bootstrap runs (100% converged) and by the fact that profiles over various values of σ_R^2 (Figure 17) and survey Q (Figure 21) indicate that the solution is fairly stable over these parameters. There is simply not enough information in these data to provide a strongly peaked likelihood surface.

Internal Retrospective

Retrospective analysis indicates a shift in scale, but not trend as survey years are removed from the model (Figure 22). There are no indications of retrospective problems in the Northern area KLAMZ model.

Appendix A5. Table 1. Bootstrap and delta method CV for whole stock KLAMZ runs.

	Biomass		F		Recruitment	
Year	Bootstrap cv	Delta cv	Bootstrap cv	Delta cv	Bootstrap cv	Delta cv
1981	27.58	28.27	50.62	28.40	24.45	46.92
1982	25.43	19.80	51.56	19.88	22.57	41.23
1983	23.79	14.73	53.04	14.81	22.82	27.38
1984	22.60	13.31	54.64	13.39	21.47	28.36
1985	21.74	13.57	56.53	13.64	20.58	26.08
1986	21.01	14.40	58.40	14.48	20.53	27.24
1987	20.57	15.31	59.28	15.38	20.62	25.93
1988	20.23	15.98	59.53	16.06	20.76	21.73
1989	19.91	16.27	59.44	16.34	21.25	23.75
1990	19.78	16.33	58.92	16.41	21.13	23.80
1991	19.71	16.31	57.99	16.38	19.89	22.66
1992	19.42	16.27	56.90	16.34	18.26	21.67
1993	18.80	16.44	57.21	16.50	19.44	19.49
1994	18.54	16.36	57.44	16.41	17.34	22.45
1995	18.05	16.05	57.04	16.09	17.15	22.85
1996	17.58	15.92	56.69	15.96	19.28	20.31
1997	17.30	15.99	56.86	16.02	19.02	23.32
1998	17.15	16.09	56.15	16.12	19.53	22.66
1999	17.07	16.20	55.91	16.24	19.90	25.74
2000	17.07	16.30	55.70	16.34	19.89	26.17
2001	17.09	16.41	55.72	16.46	19.21	24.45
2002	17.12	16.54	56.11	16.60	19.84	27.88
2003	17.20	16.64	57.09	16.70	20.79	29.18
2004	17.33	16.76	58.46	16.83	21.33	29.29
2005	17.49	16.91	59.91	16.97	21.21	28.56
2006	17.63	17.05	61.53	17.13	20.67	26.88
2007	17.75	17.22	63.41	17.30	20.78	23.39
2008	17.79	17.34	64.94	17.42	20.33	28.27
2009	17.82	17.52	66.30	17.59	21.00	28.79
2010	17.84	17.82	67.19	17.89	22.59	25.45
2011	17.88	18.12	67.41	18.19	NA	NA
mean	19.23	16.72	58.32	16.78	20.45	26.40

Appendix A5. Table 2. Mean, median and quantiles of relative biomass change from 2008 to 2011, comparing projections from the last assessment to the current KLAMZ model results.

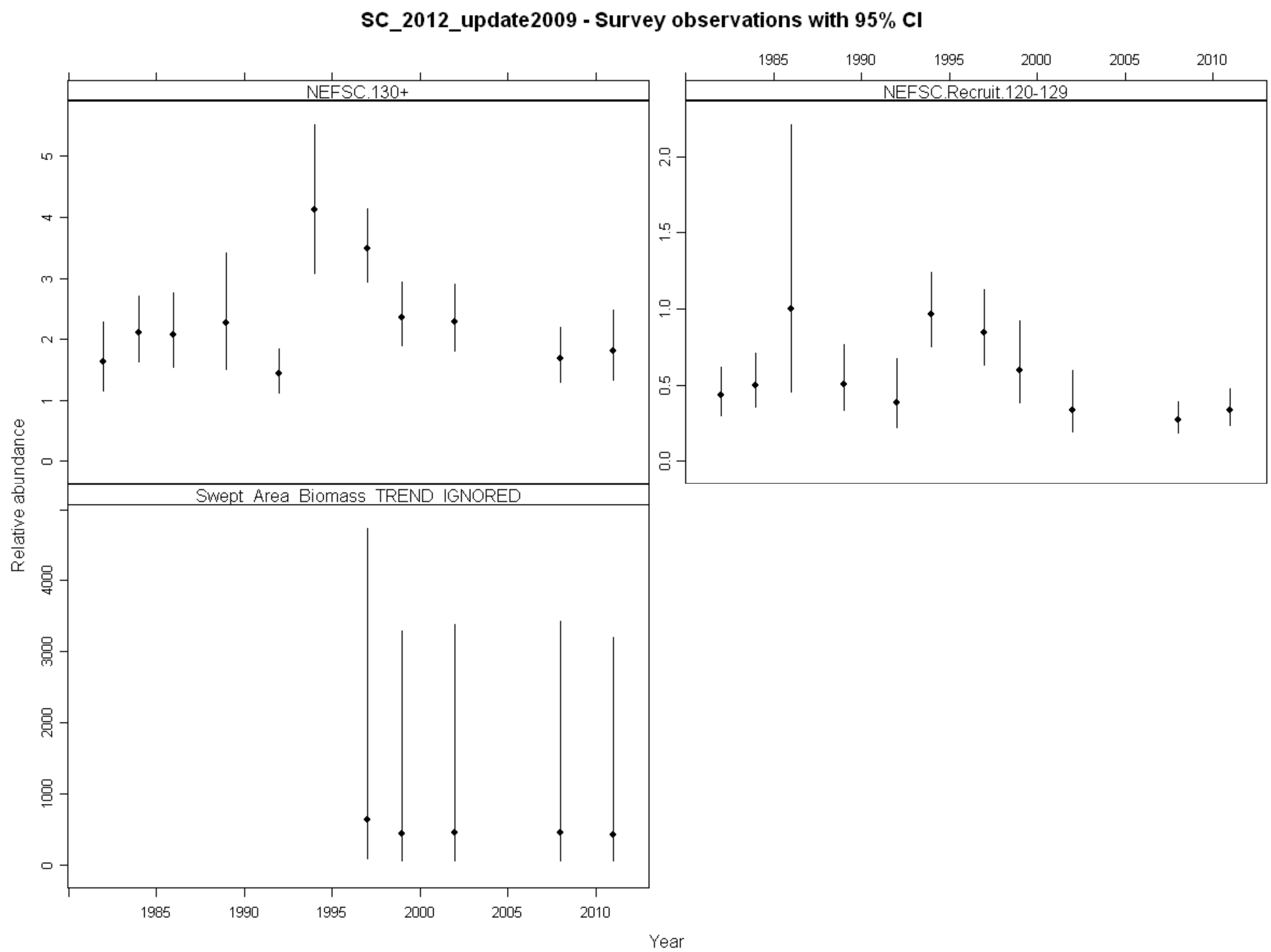
	change from 2008 to 2011	
Statistic	Proj 2009	This Assessment
Q10%	-7.54%	-14.63%
Mean	-5.72%	-13.55%
Median	-5.63%	-13.50%
Q90%	-3.80%	-12.50%

Appendix A5. Table 3. Bootstrap and delta method CV for southern area KLAMZ runs.

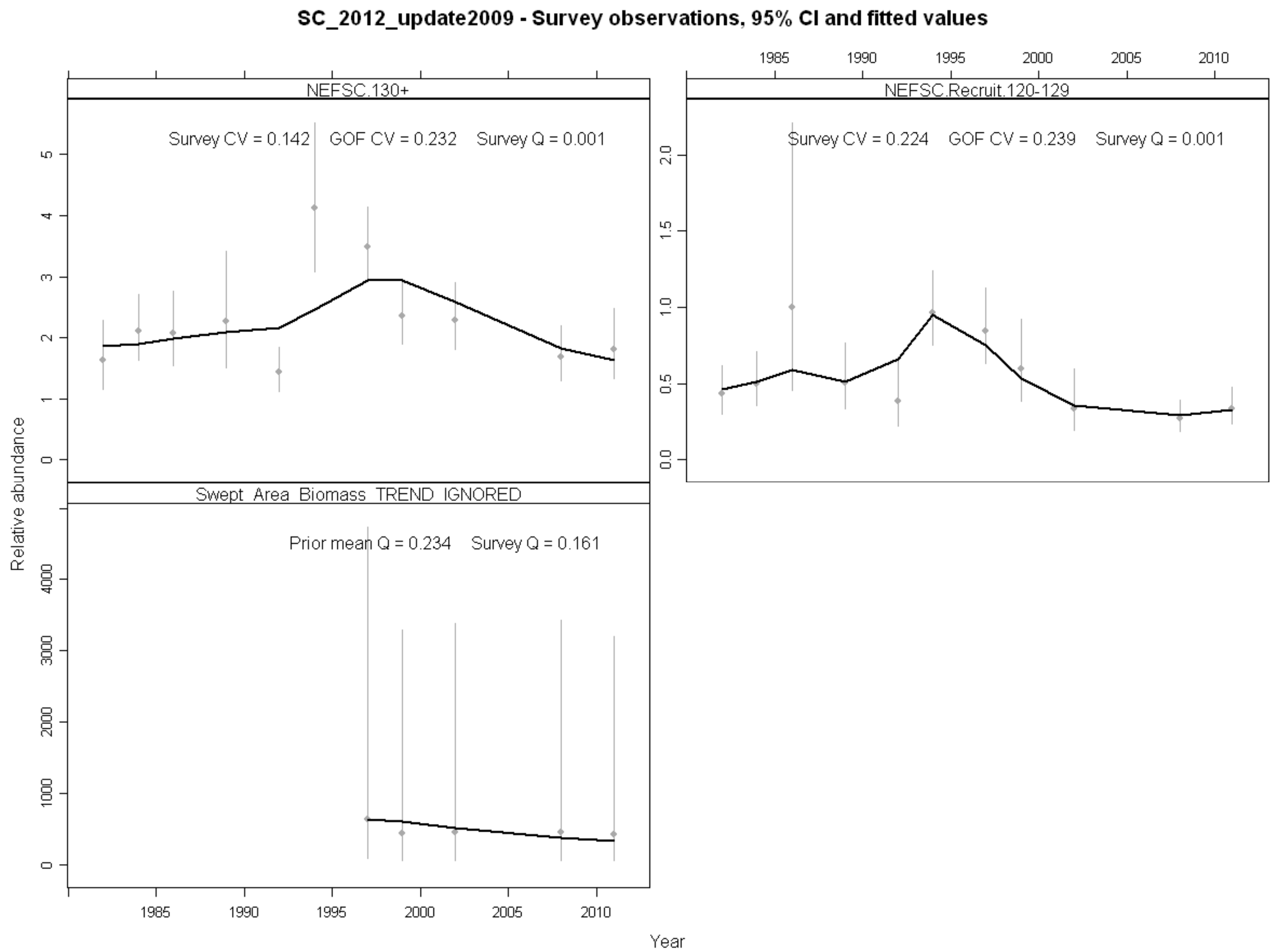
	Biomass		Fishing Mortality		Recruitment	
Year	Bootstrap CV	Delta CV	Bootstrap CV	Delta CV	Bootstrap CV	Delta CV
1981	56.48	5.46	25.60	5.56	59.88	16.53
1982	57.17	6.30	24.28	6.42	55.42	15.85
1983	57.74	7.78	23.75	7.91	54.17	15.11
1984	58.08	9.10	23.61	9.24	53.81	14.71
1985	58.59	10.15	23.68	10.32	53.84	14.26
1986	59.07	11.00	23.87	11.17	57.68	13.82
1987	60.19	11.61	24.04	11.82	60.74	13.37
1988	61.47	12.10	24.16	12.33	62.41	12.86
1989	62.89	12.47	24.19	12.72	56.66	12.61
1990	63.19	12.72	24.10	12.96	51.71	12.26
1991	62.69	12.82	23.90	13.03	47.89	11.84
1992	61.13	12.75	23.63	12.97	43.65	11.31
1993	58.90	12.60	23.42	12.82	45.27	10.88
1994	57.26	12.41	23.30	12.59	41.87	11.00
1995	55.59	12.24	23.12	12.39	40.87	10.97
1996	54.10	12.06	22.91	12.19	42.47	10.90
1997	53.12	11.87	22.70	11.99	47.17	11.21
1998	52.97	11.79	22.53	11.93	51.52	11.27
1999	53.34	11.77	22.57	11.92	54.75	11.36
2000	54.14	11.83	22.67	11.99	56.99	11.38
2001	55.16	11.93	22.82	12.13	58.42	11.32
2002	56.43	12.11	23.08	12.36	55.56	11.37
2003	57.89	12.38	23.44	12.67	52.08	11.36
2004	59.41	12.71	23.87	13.04	48.71	11.06
2005	60.83	13.12	24.26	13.46	49.87	11.70
2006	62.18	13.45	24.75	13.89	51.36	11.98
2007	64.03	13.92	25.43	14.46	53.19	12.00
2008	66.27	14.55	26.14	15.14	51.26	12.98
2009	68.06	15.09	27.00	15.70	50.15	13.63
2010	69.15	15.57	27.88	16.18	50.43	14.33
2011	69.29	15.97	28.85	16.66	NA	NA
mean	59.57	11.99	24.18	12.26	51.99	12.51

Appendix A5. Table 4. Bootstrap and delta method CV for GBK area KLAMZ runs.

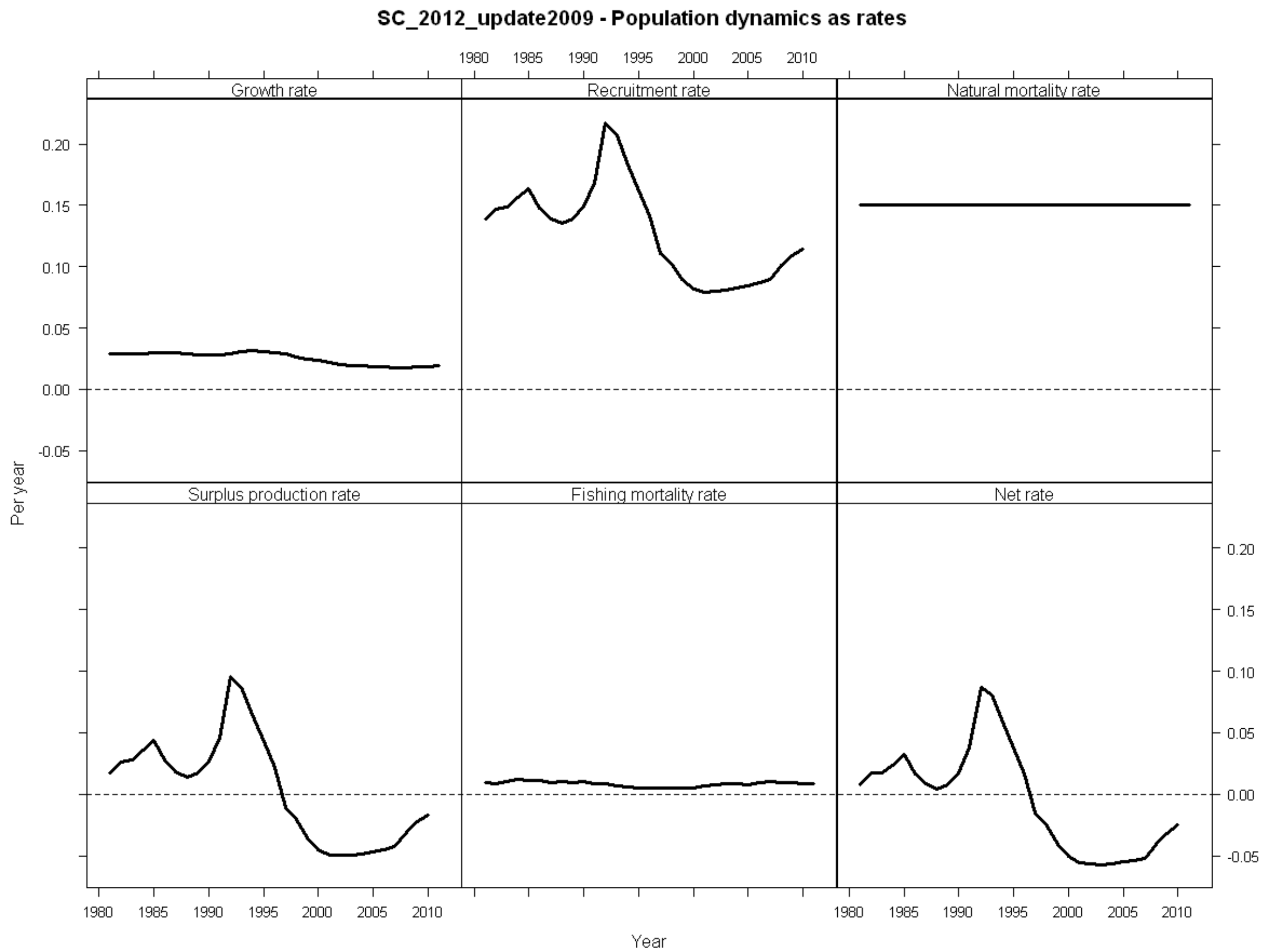
	Biomass		Fishing Mortality		Recruitment	
Year	Bootstrap CV	Delta CV	Bootstrap CV	Delta CV	Bootstrap CV	Delta CV
1981	70.64	99.01	NA	NA	27.70	97.13
1982	65.04	99.13	NA	NA	27.76	97.14
1983	59.55	99.15	NA	NA	27.69	97.43
1984	54.31	99.16	46.48	97.38	25.06	97.97
1985	49.38	99.14	41.49	96.97	23.96	97.70
1986	44.58	99.14	37.18	96.54	24.20	97.53
1987	39.84	99.16	33.47	96.08	24.57	97.44
1988	35.41	99.18	30.24	95.70	24.62	97.44
1989	31.50	99.21	27.50	95.45	24.61	97.55
1990	28.19	99.23	25.27	95.27	24.41	97.81
1991	25.57	99.24	NA	NA	24.70	97.83
1992	23.53	99.22	NA	NA	22.19	98.03
1993	21.99	99.19	NA	NA	21.33	98.45
1994	20.72	99.12	NA	NA	19.37	98.45
1995	19.62	99.01	NA	NA	17.95	98.76
1996	18.40	98.87	NA	NA	18.18	98.43
1997	16.99	98.72	NA	NA	14.43	98.30
1998	15.49	98.55	NA	NA	15.30	98.41
1999	14.03	98.35	NA	NA	14.53	98.02
2000	12.70	98.10	NA	NA	15.37	98.22
2001	11.65	97.76	NA	NA	16.78	97.74
2002	10.93	97.38	NA	NA	18.34	97.42
2003	10.65	97.02	NA	NA	20.15	97.26
2004	10.82	96.63	NA	NA	21.50	97.11
2005	11.36	96.18	NA	NA	22.32	97.25
2006	12.13	95.92	NA	NA	23.11	97.72
2007	12.98	95.69	NA	NA	25.04	97.79
2008	13.84	95.55	NA	NA	25.17	98.13
2009	14.67	94.86	14.67	98.91	26.83	96.86
2010	15.46	94.10	15.45	99.08	30.11	95.66
2011	16.28	93.27	16.23	99.16	NA	NA
mean	26.07	97.88	28.80	97.05	22.24	97.70



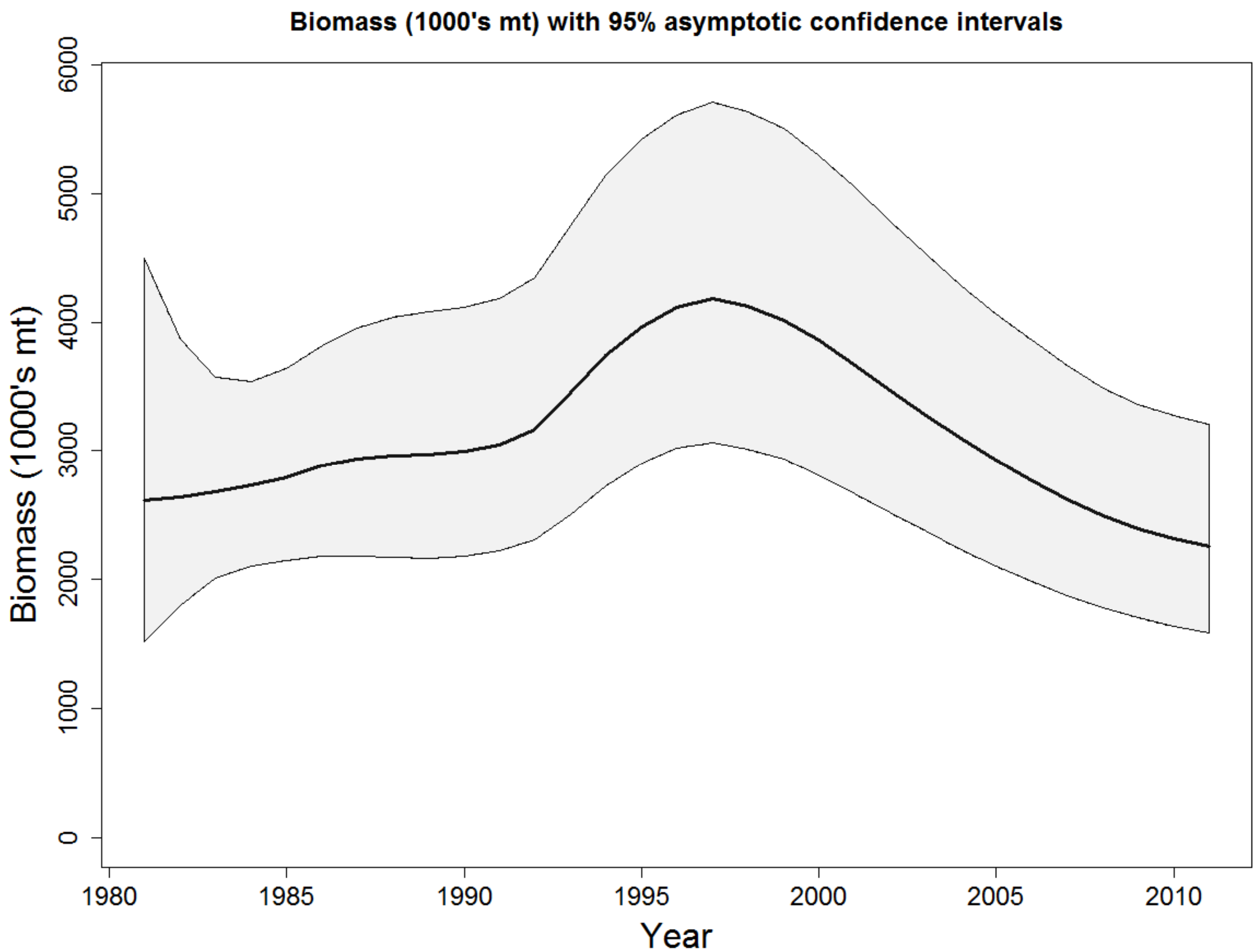
Appendix A5. Figure 1. Whole stock survey data and swept area biomass estimates with approximate 95% confidence intervals.



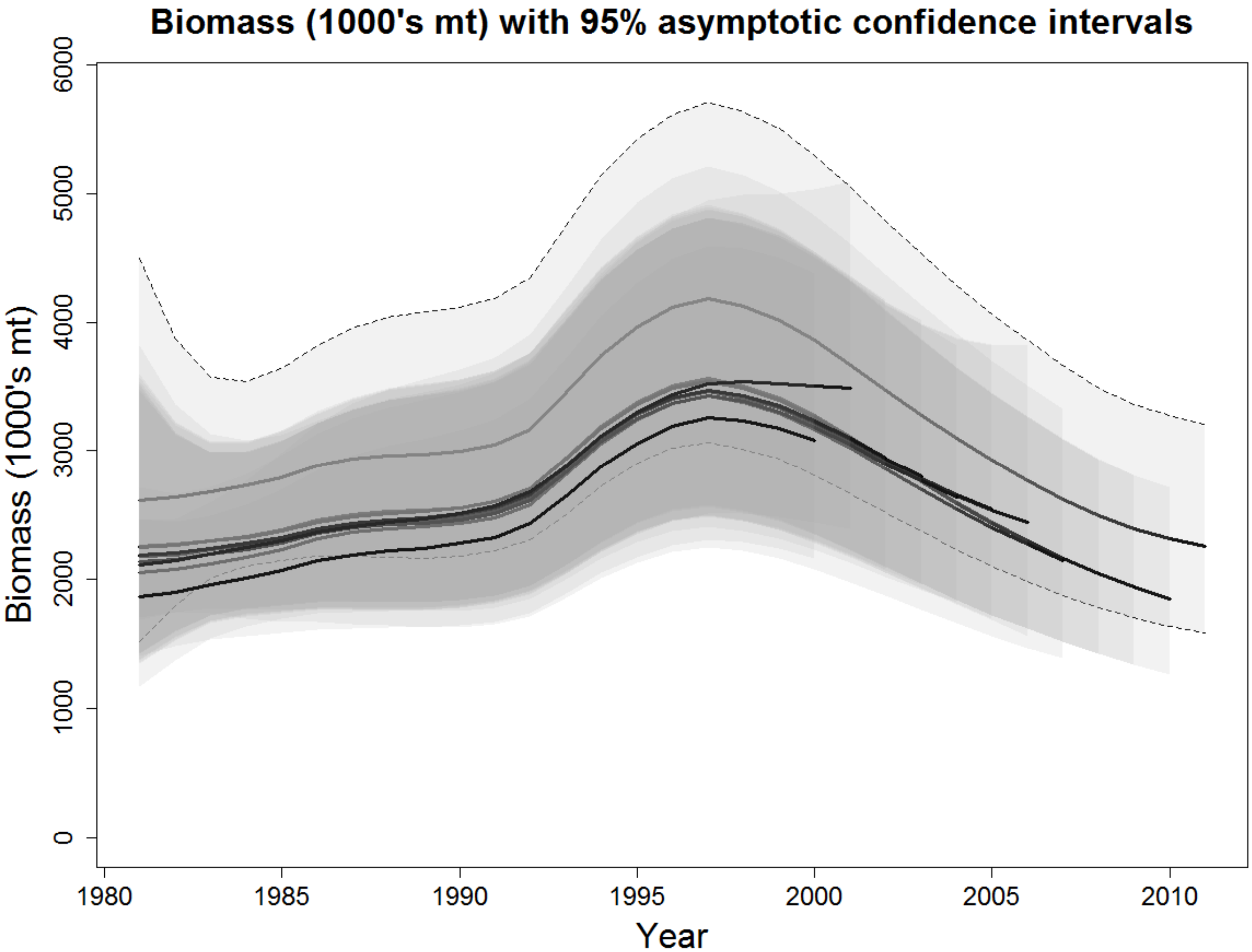
Appendix A5. Figure 2. Whole stock survey data and swept area biomass estimates with approximate 95% confidence intervals and KLAMZ model fits with goodness of fit statistics and estimated catchability parameters.



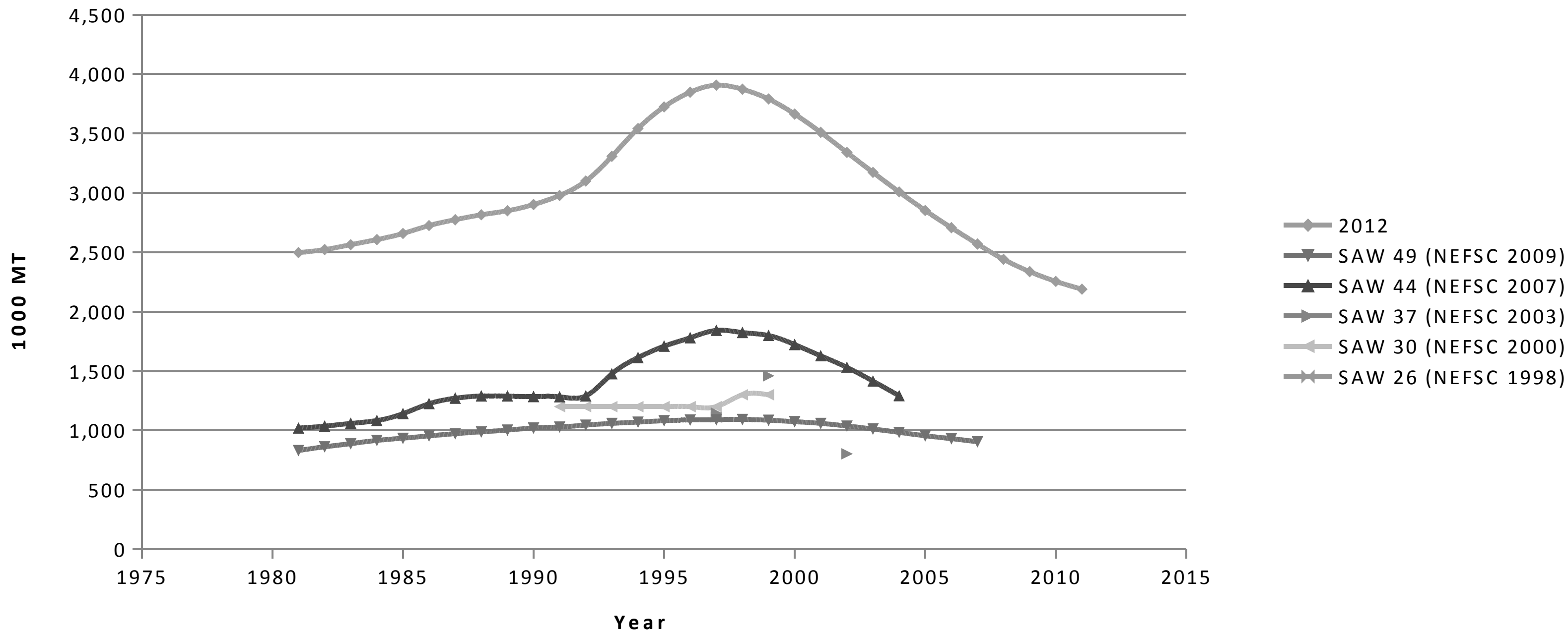
Appendix A5. Figure 3. Some population dynamics, shown as rates, estimated in KLAMZ for the whole stock.



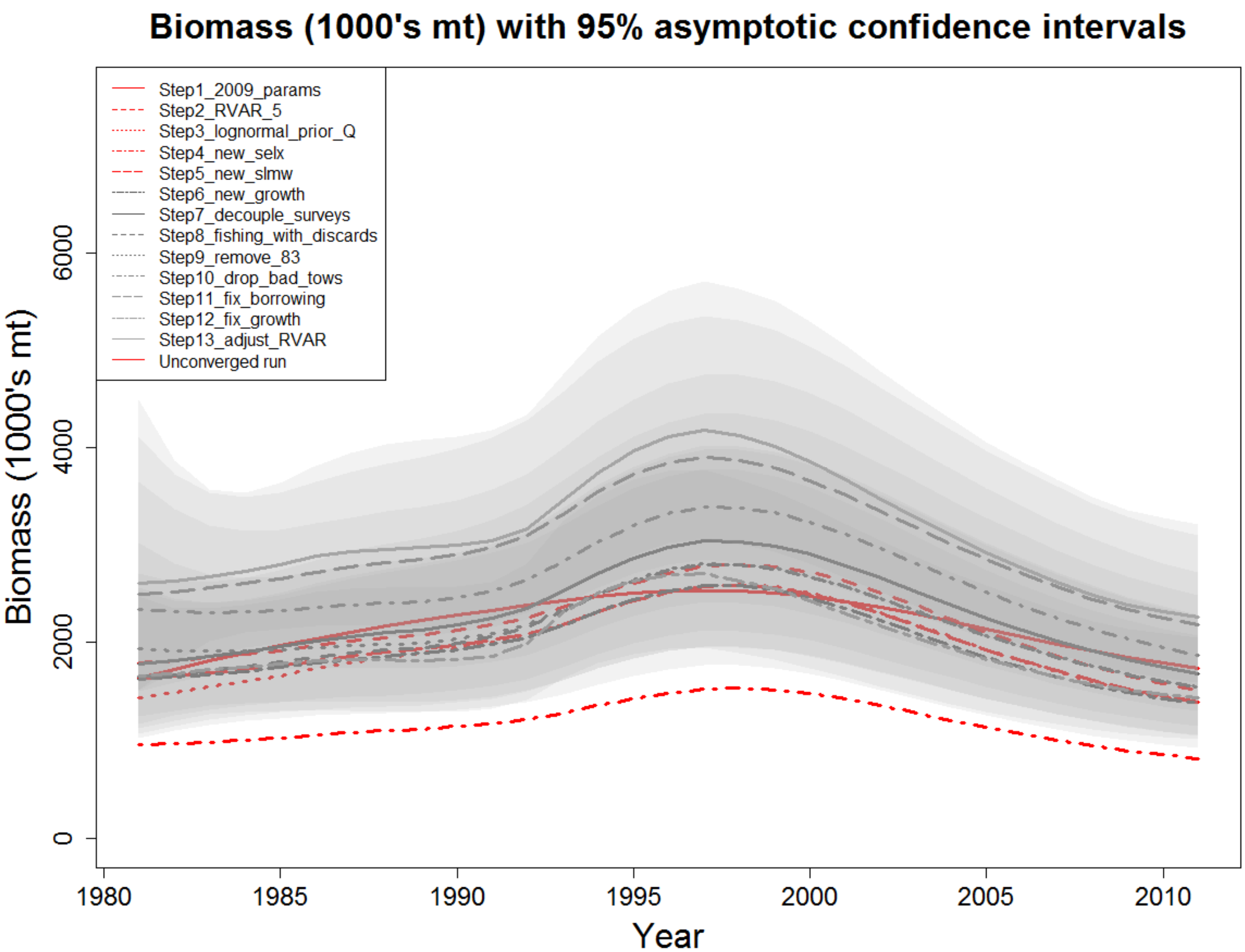
Appendix A5. Figure 4. Total biomass (1000 mt) estimated for the whole stock.



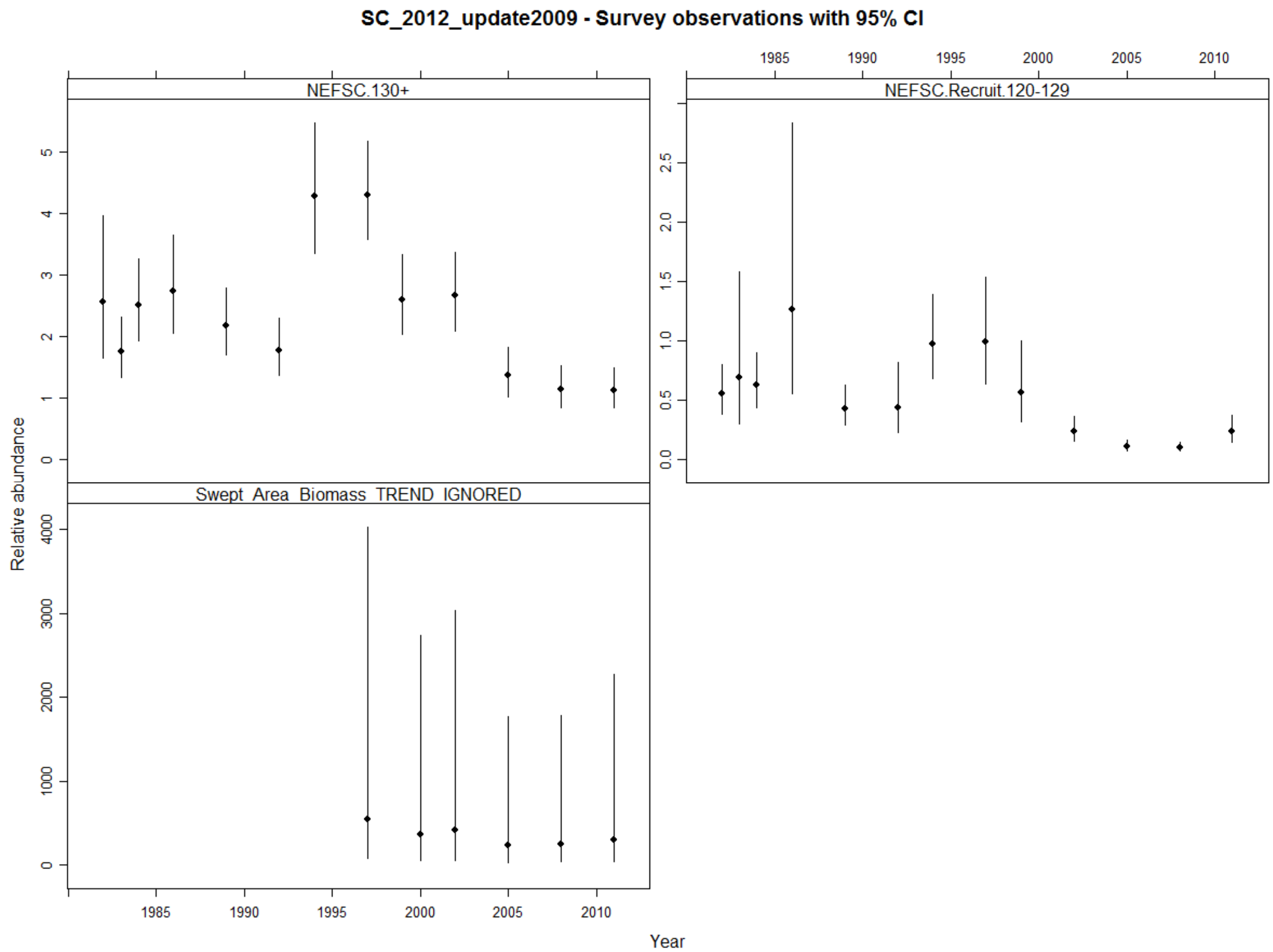
Appendix A5. Figure 5. Retrospective patterns in total biomass for the years 2000-2011 using the base case whole stock KLAMZ model.



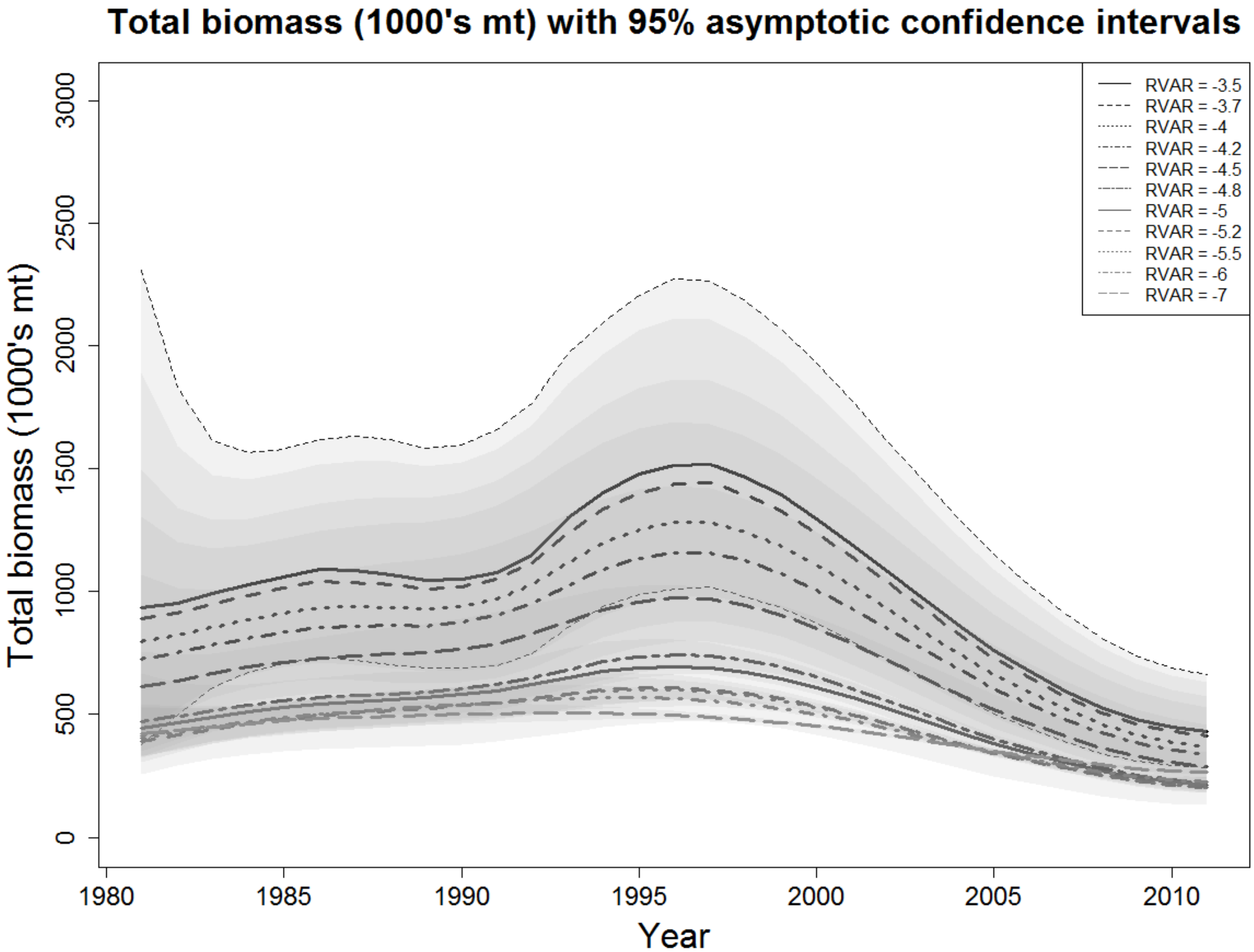
Appendix A5. Figure 6. Historical retrospective pattern in basecase whole stock KLAMZ models.



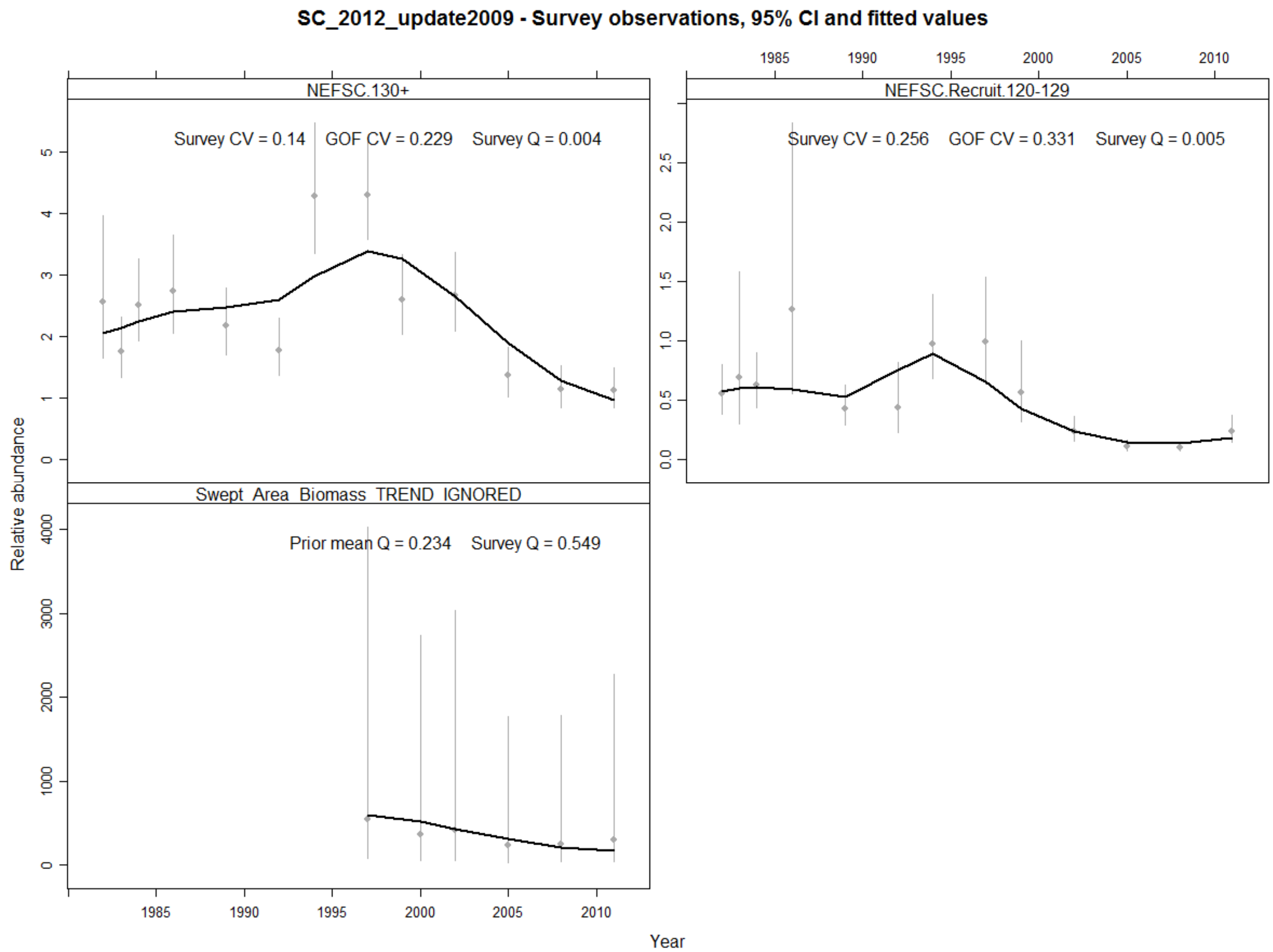
Appendix A5. Figure 7. Build a bridge. The steps involved in updating the KLAMZ model from the 2009 assessment to the current base case whole stock KLAMZ version. Not all runs converged (red lines) and so asymptotic confidence intervals based on the delta method were not always available.



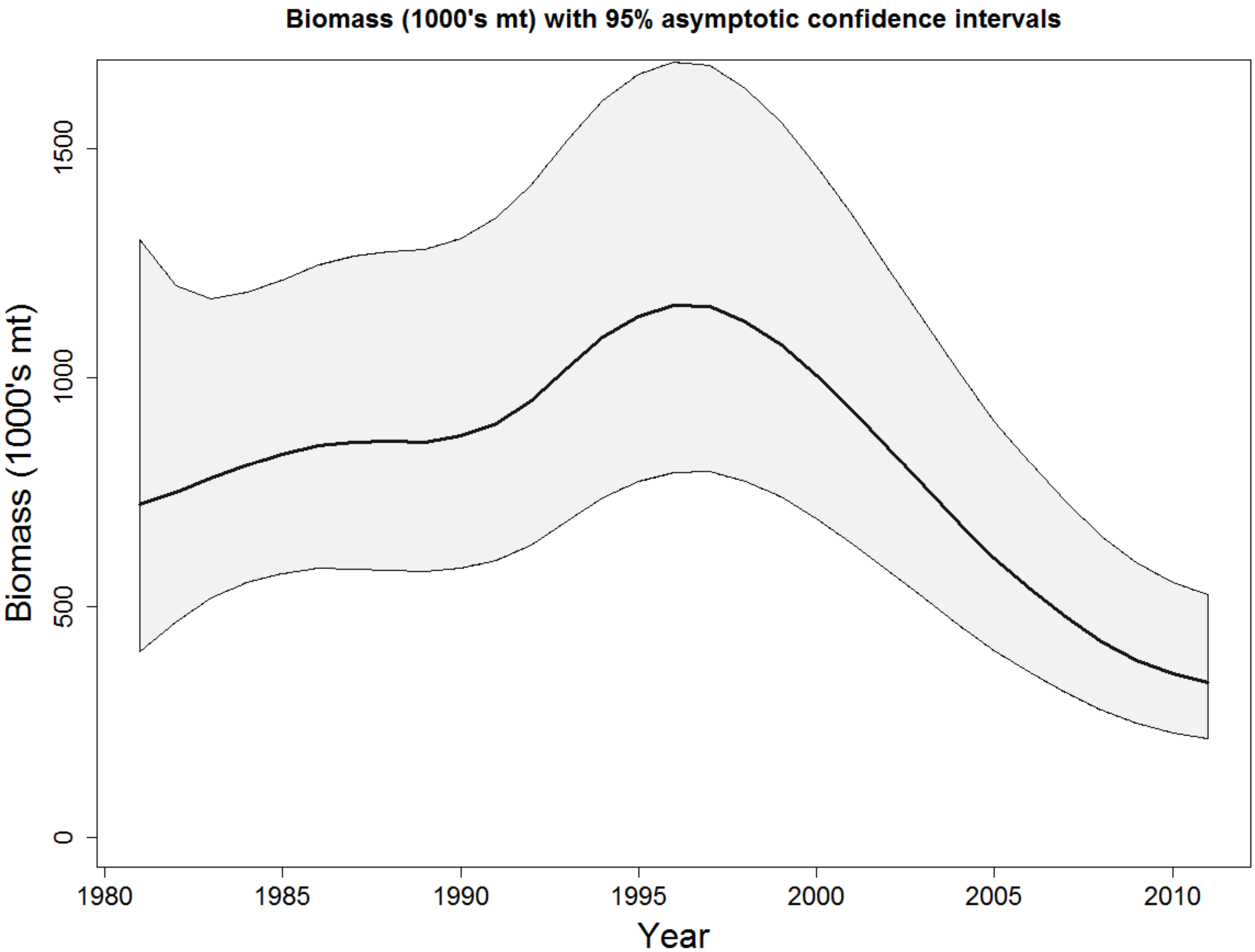
Appendix A5. Figure 8. The data with approximate 95% confidence intervals used to model the southern area (SVA to SNE) with KLAMZ.



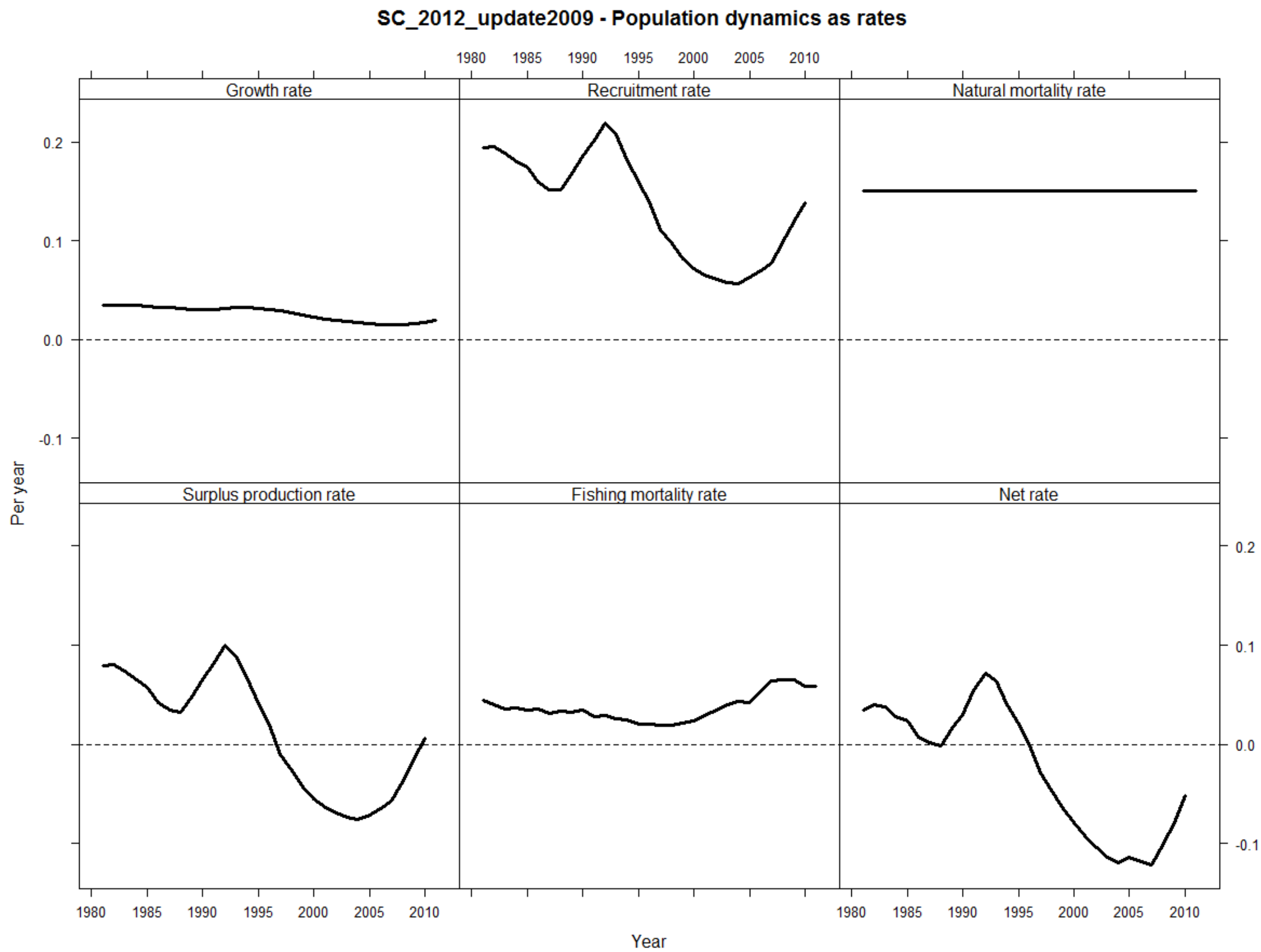
Appendix A5. Figure 9. Sensitivity to σ_R^2 the variance in the random walk recruitment parameter (RVAR).



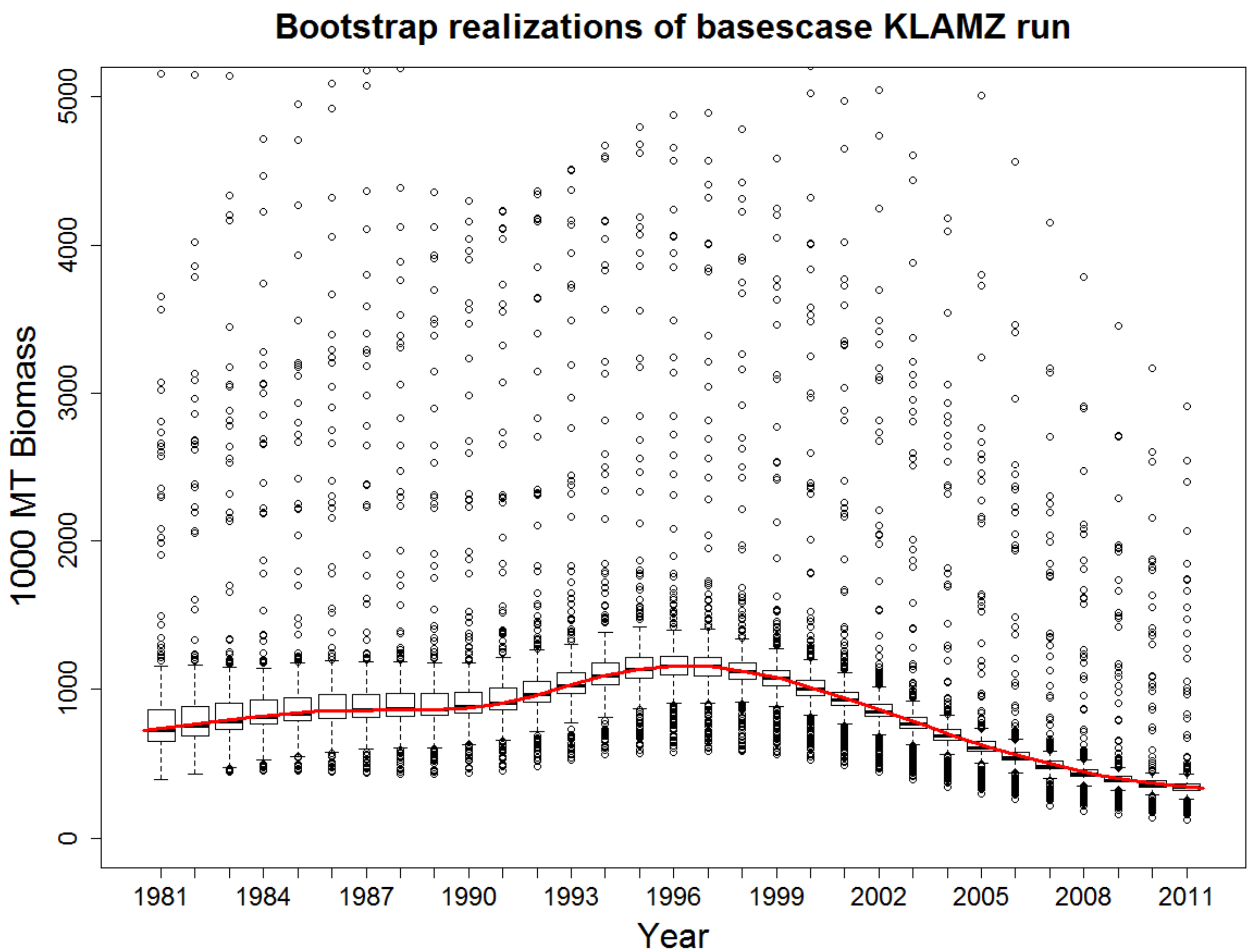
Appendix A5. Figure 10. KLAMZ model fit to the southern area.



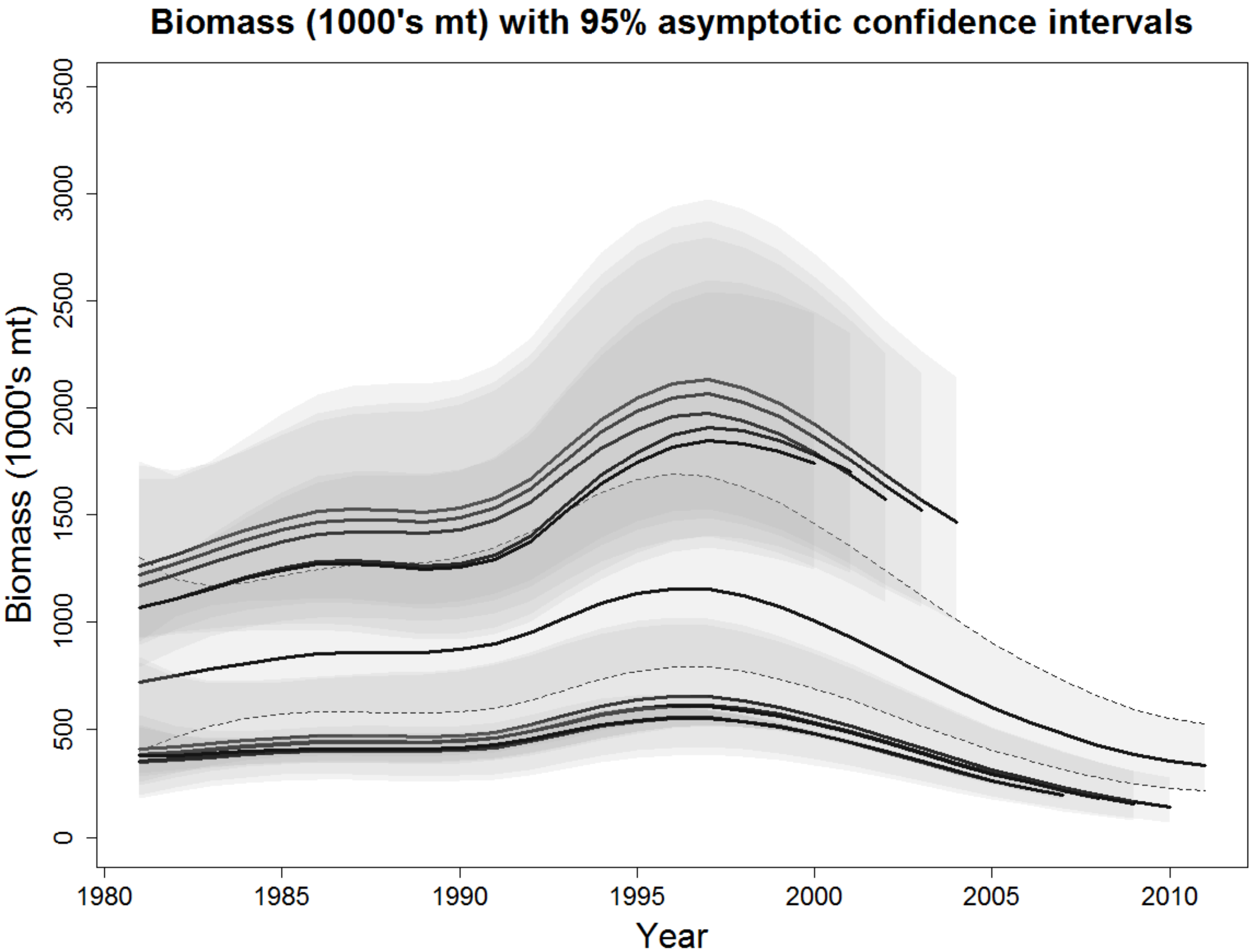
Appendix A5. Figure 11. Biomass (1000 mt) estimated using KLAMZ for the southern area.



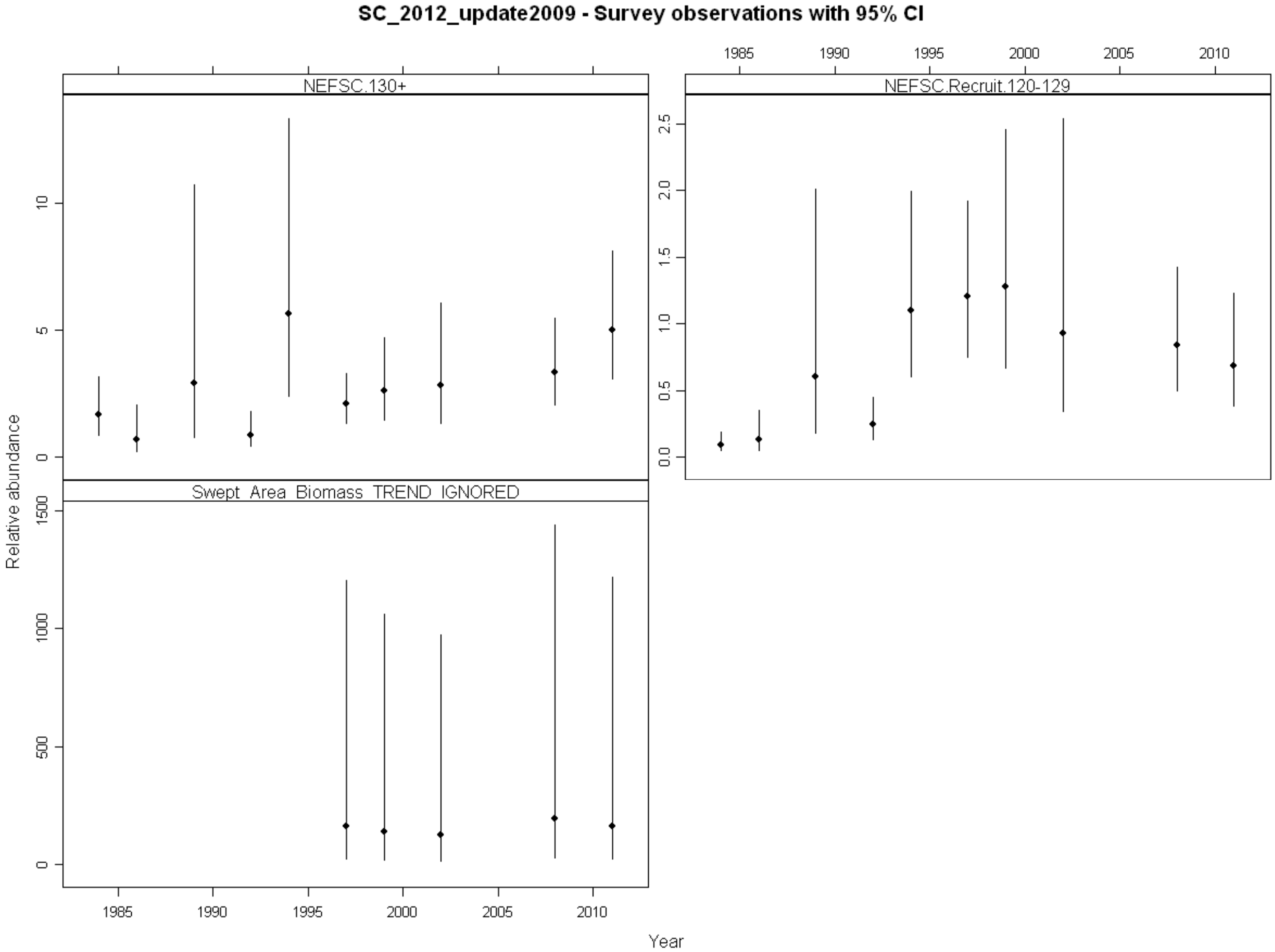
Appendix A5. Figure 12. Population dynamics as rates over time for the southern area.



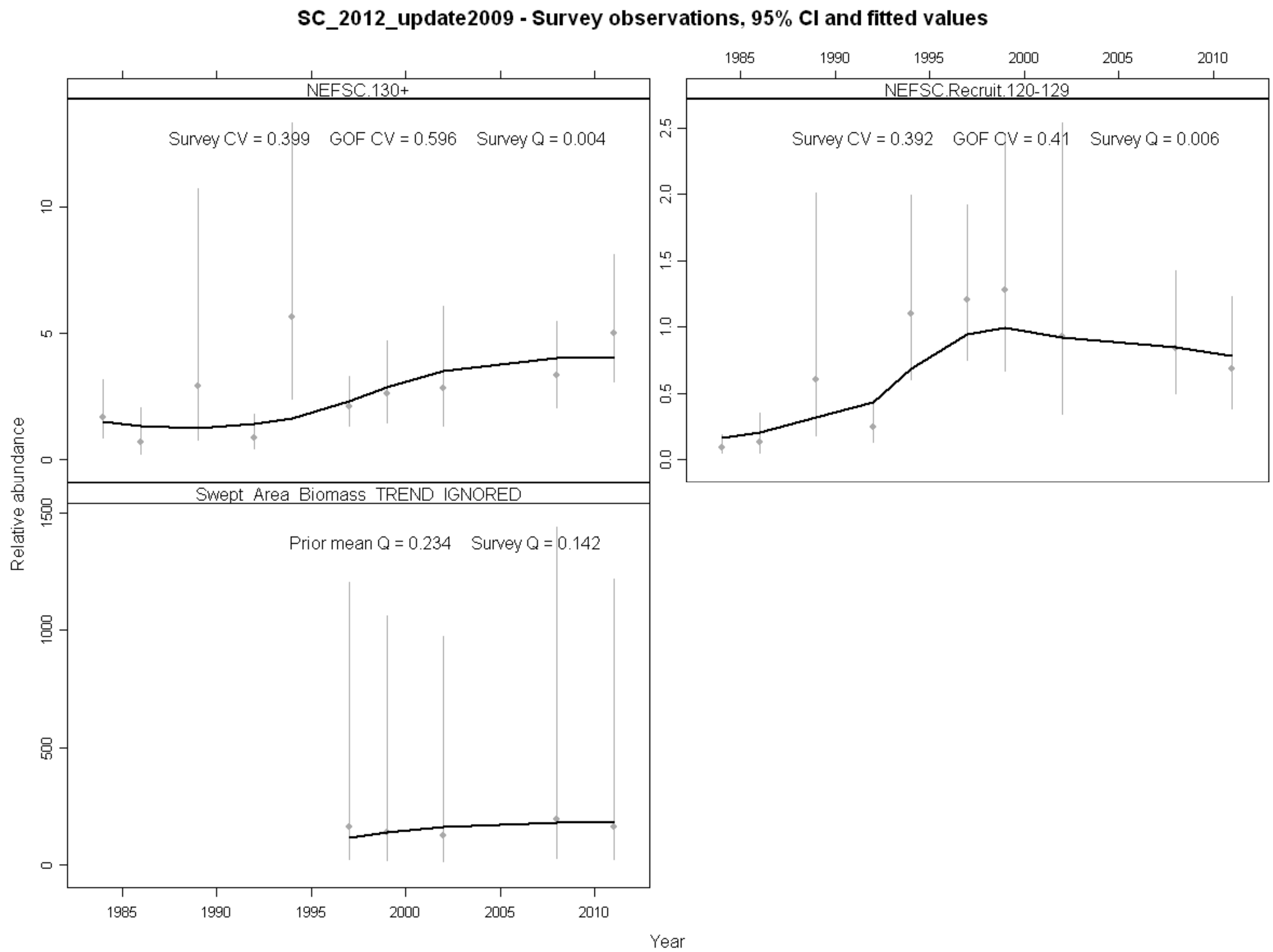
Appendix A5. Figure 13. Bootstrap iterations of the KLAMZ model biomass estimates for the southern area. The base case is shown in red.



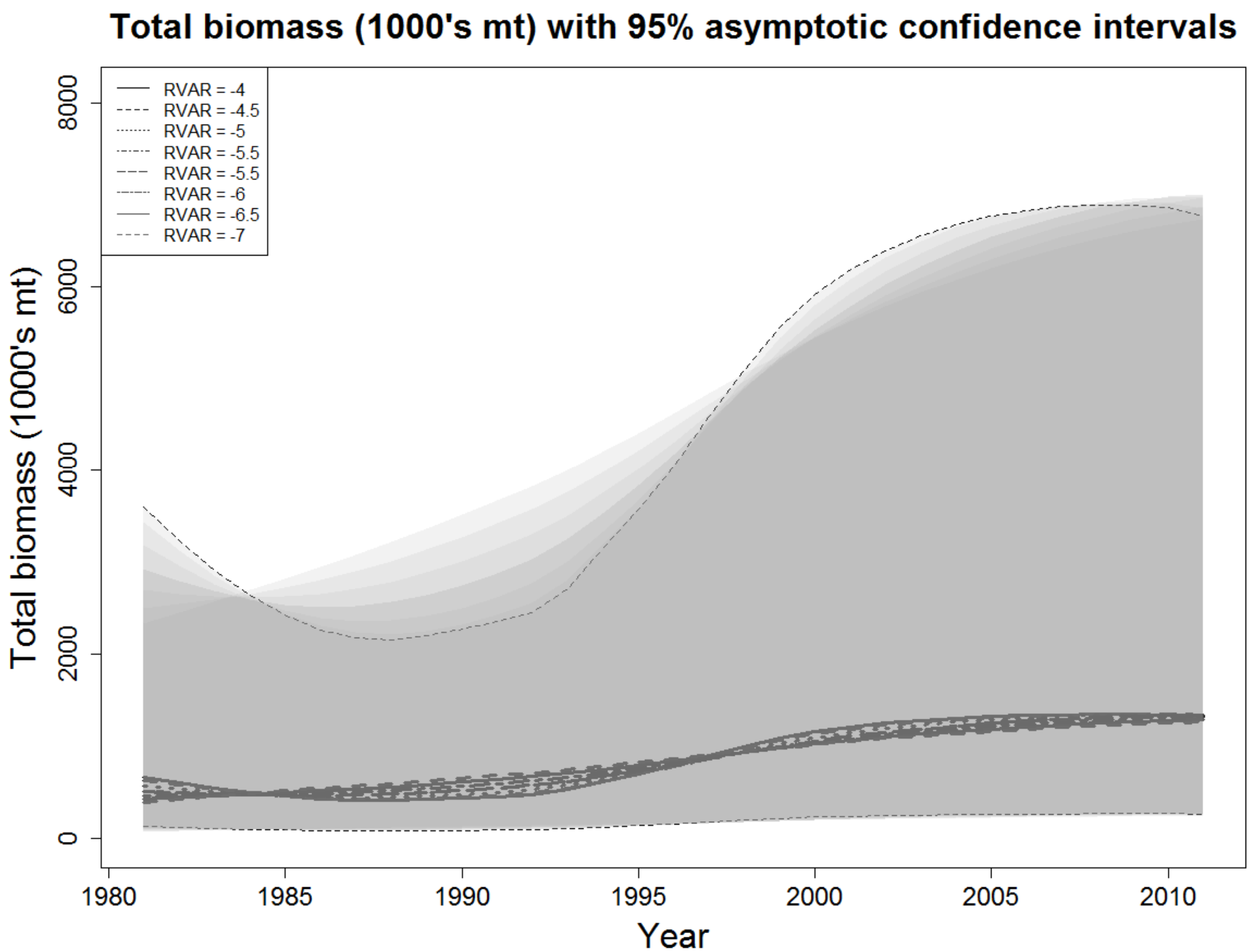
Appendix A5. Figure 14. Retrospective patterns in total biomass for the years 2000-2011 using the base case southern area KLAMZ model.



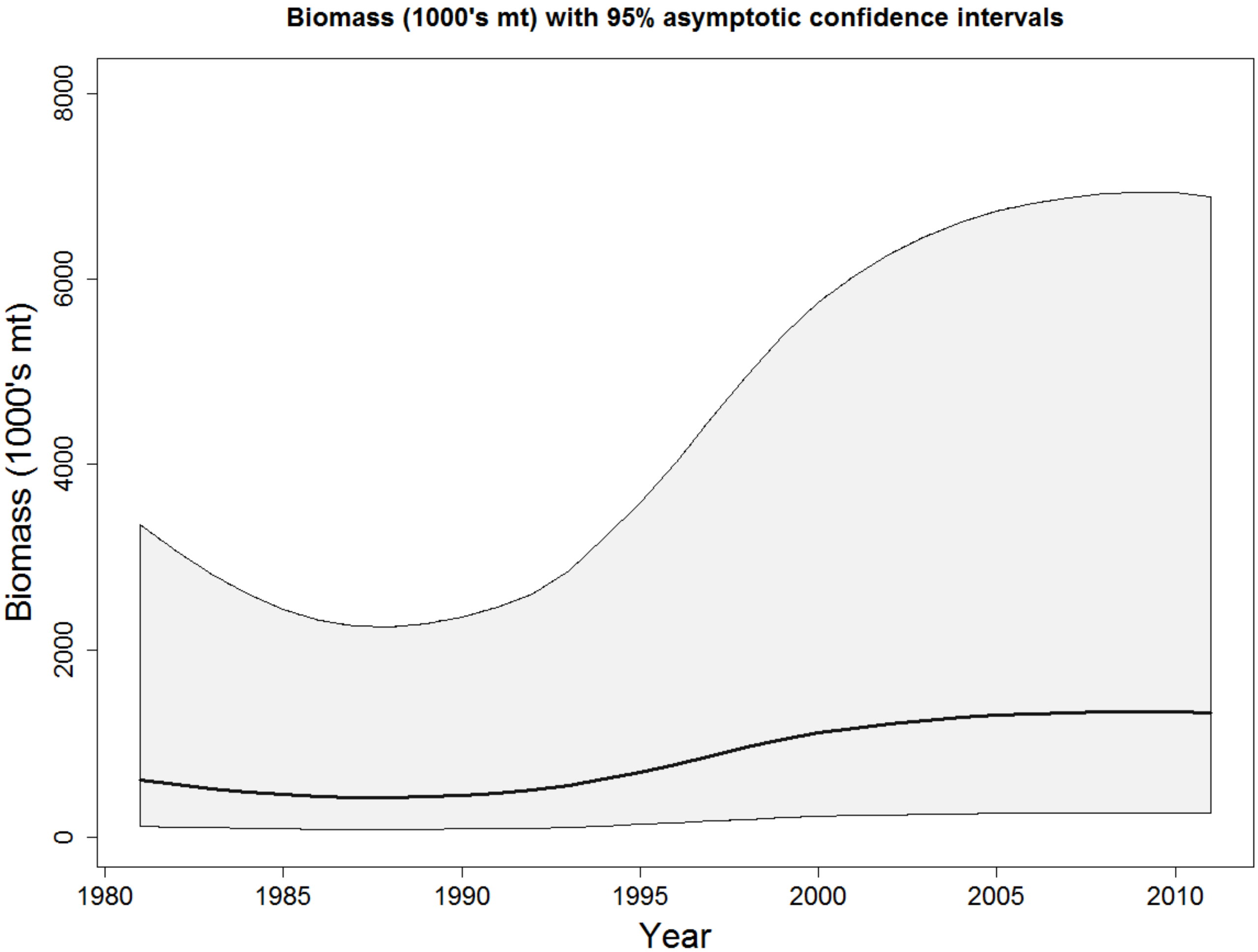
Appendix A5. Figure 15. The data with approximate 95% confidence intervals used to model the northern area (GBK) with KLAMZ.



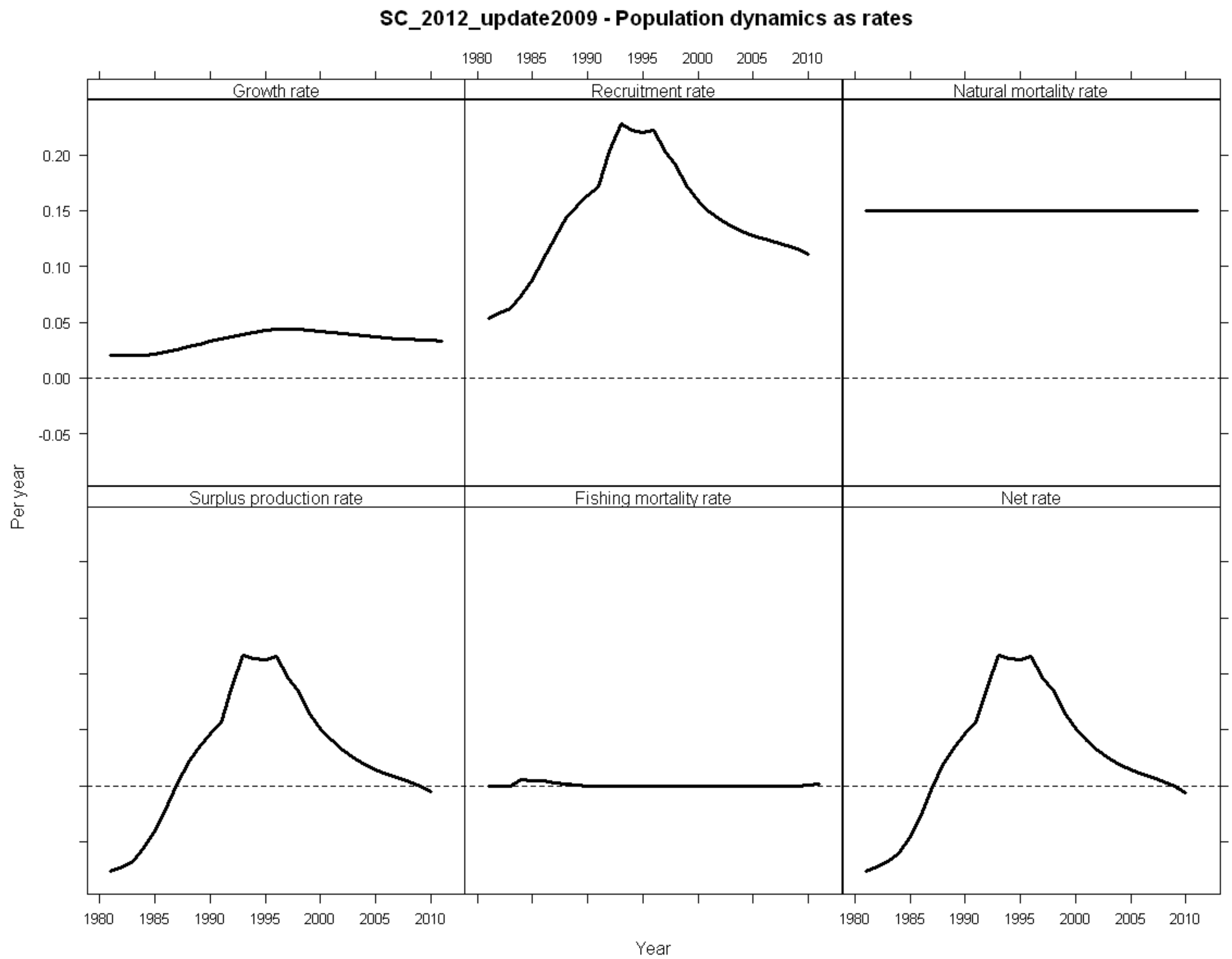
Appendix A5. Figure 16. KLAMZ model fit to the northern area (GBK).



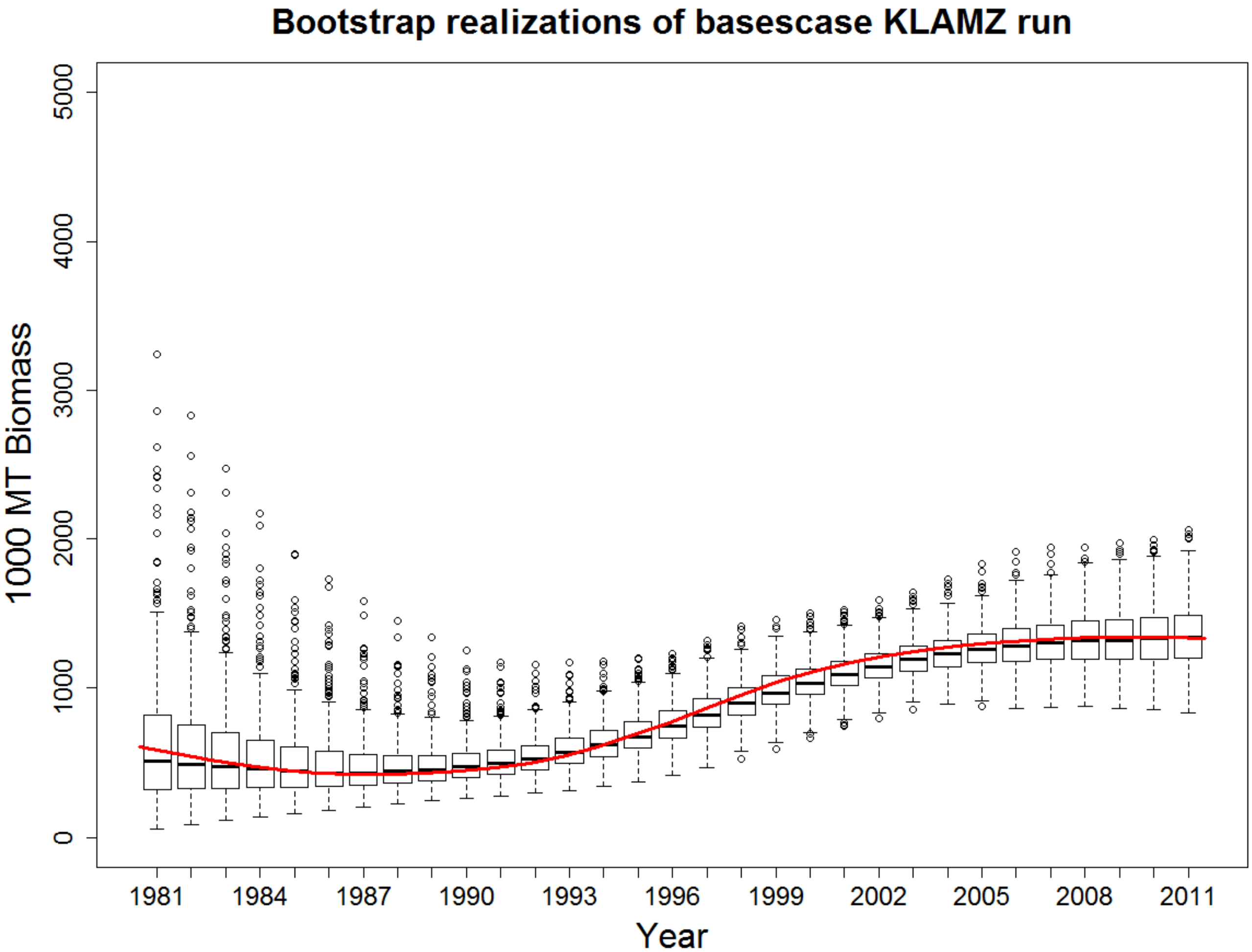
Appendix A5. Figure 17. Sensitivity to σ_R^2 in total biomass for northern area KLAMZ model fit.



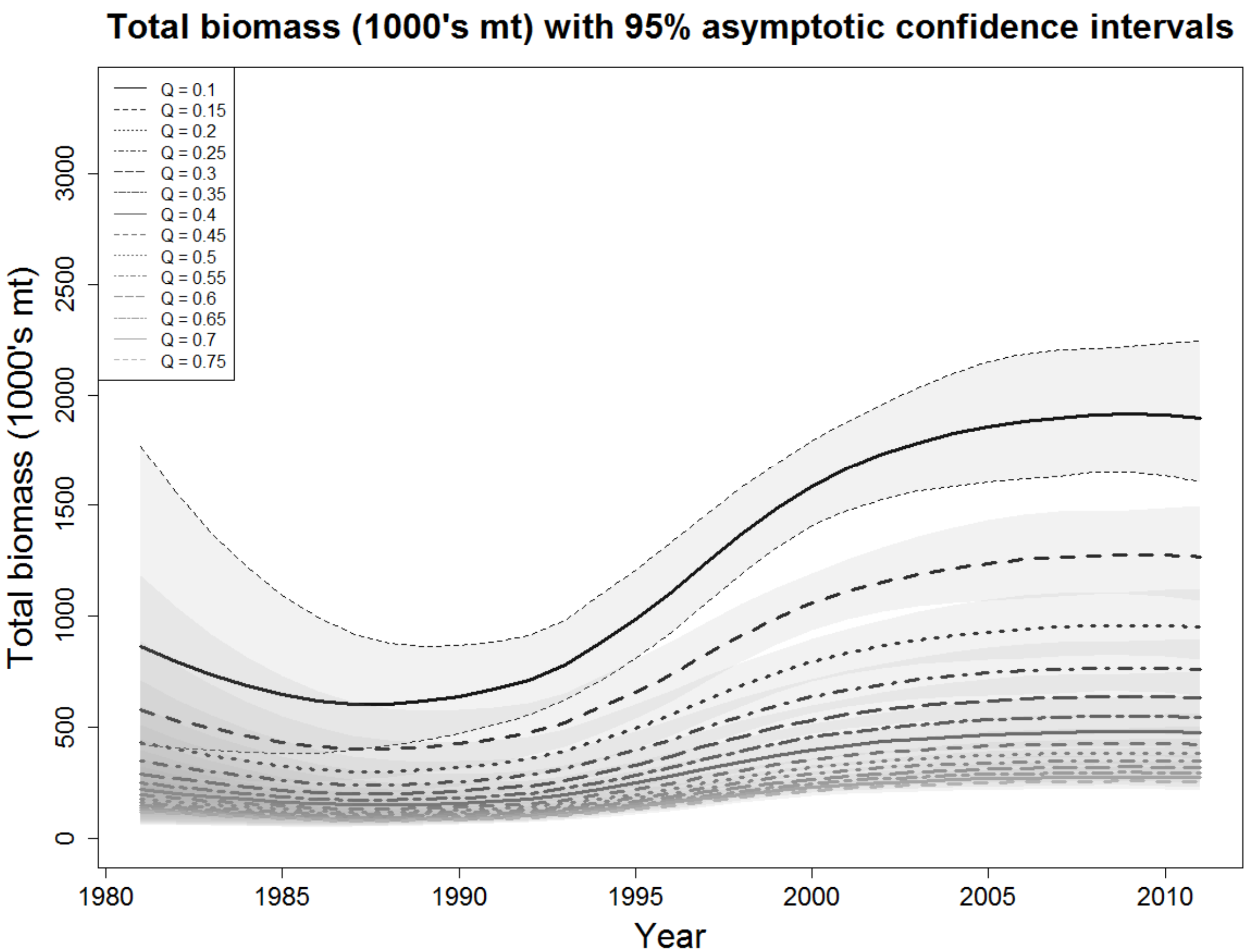
Appendix A5. Figure 18. Trend in biomass in the northern area.



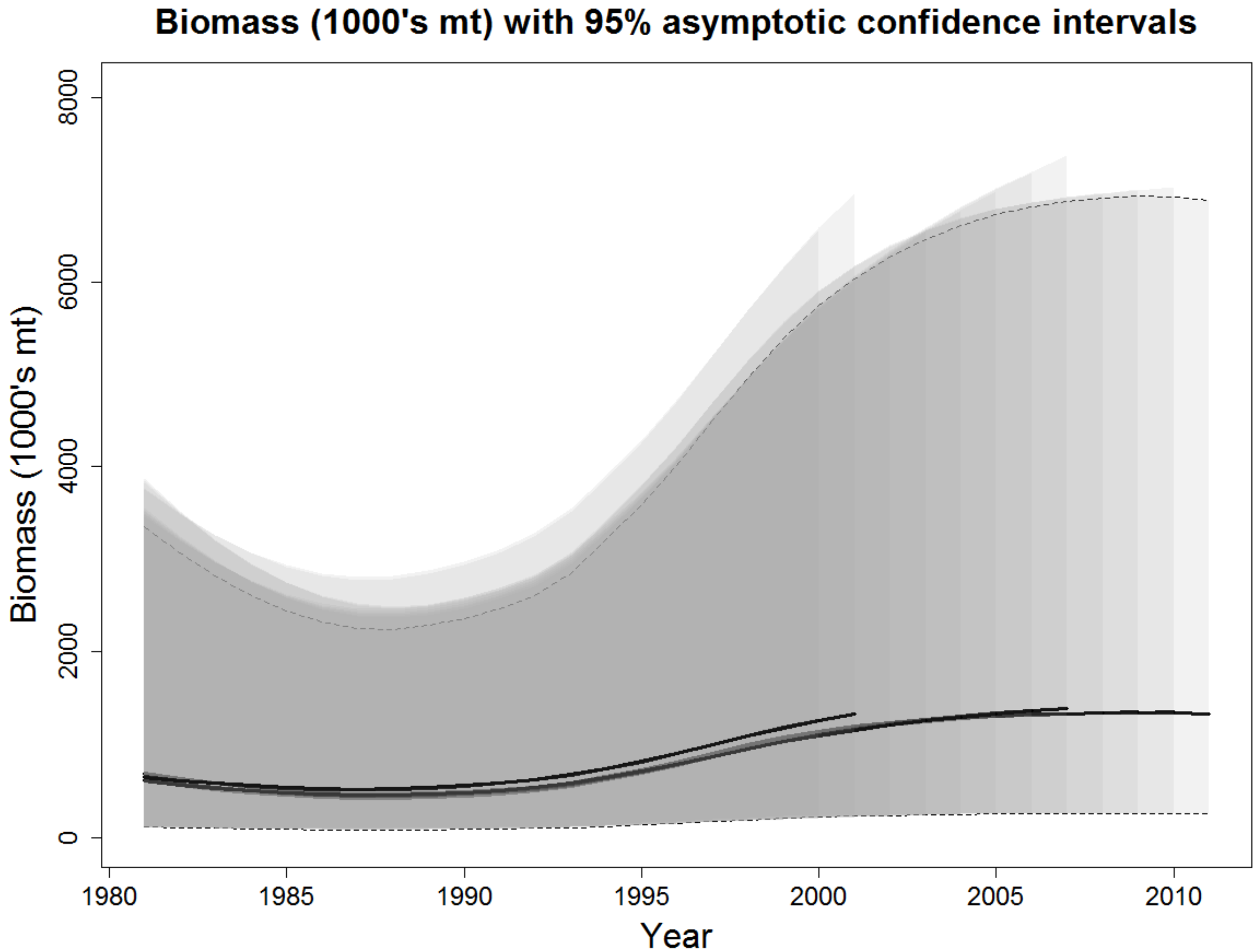
Appendix A5. Figure 19. Population dynamics as rates from KLAMZ model on northern area.



Appendix A5. Figure 20. Bootstrap iterations of the KLAMZ model biomass estimates for the northern area. The base case is shown in red.



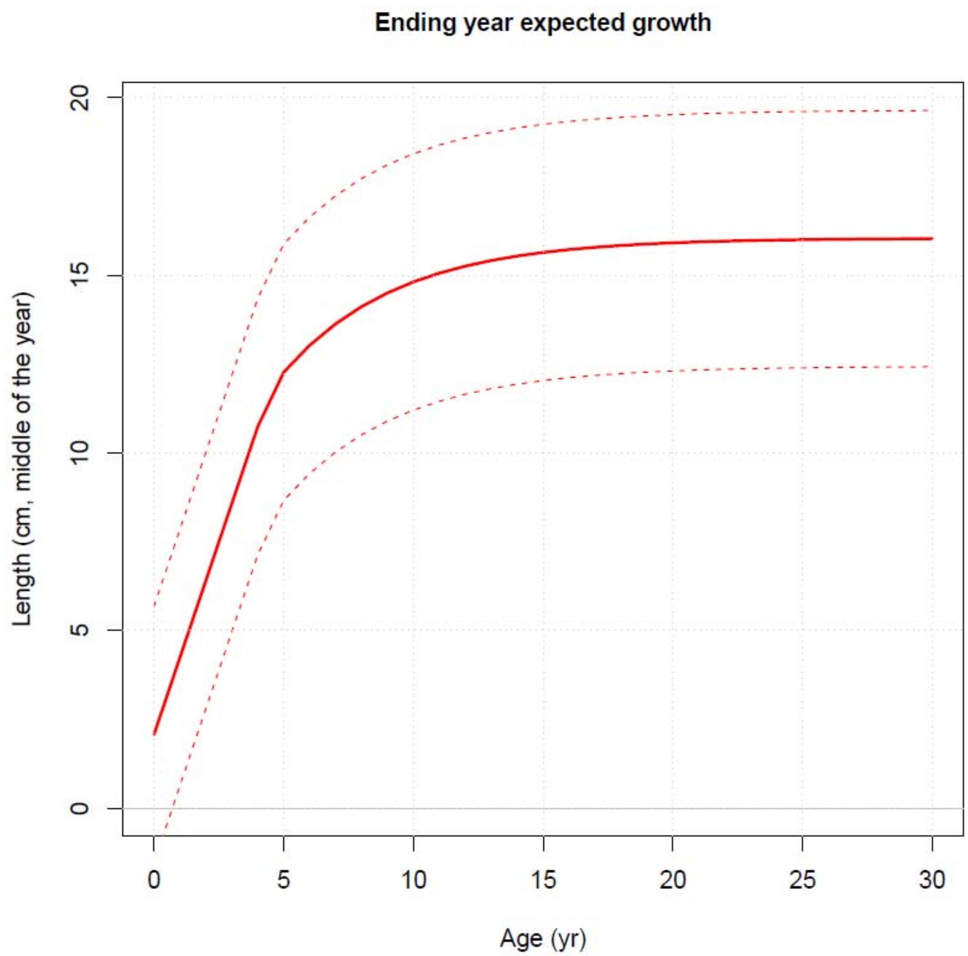
Appendix A5. Figure 21. Profile over survey Q for the northern area.

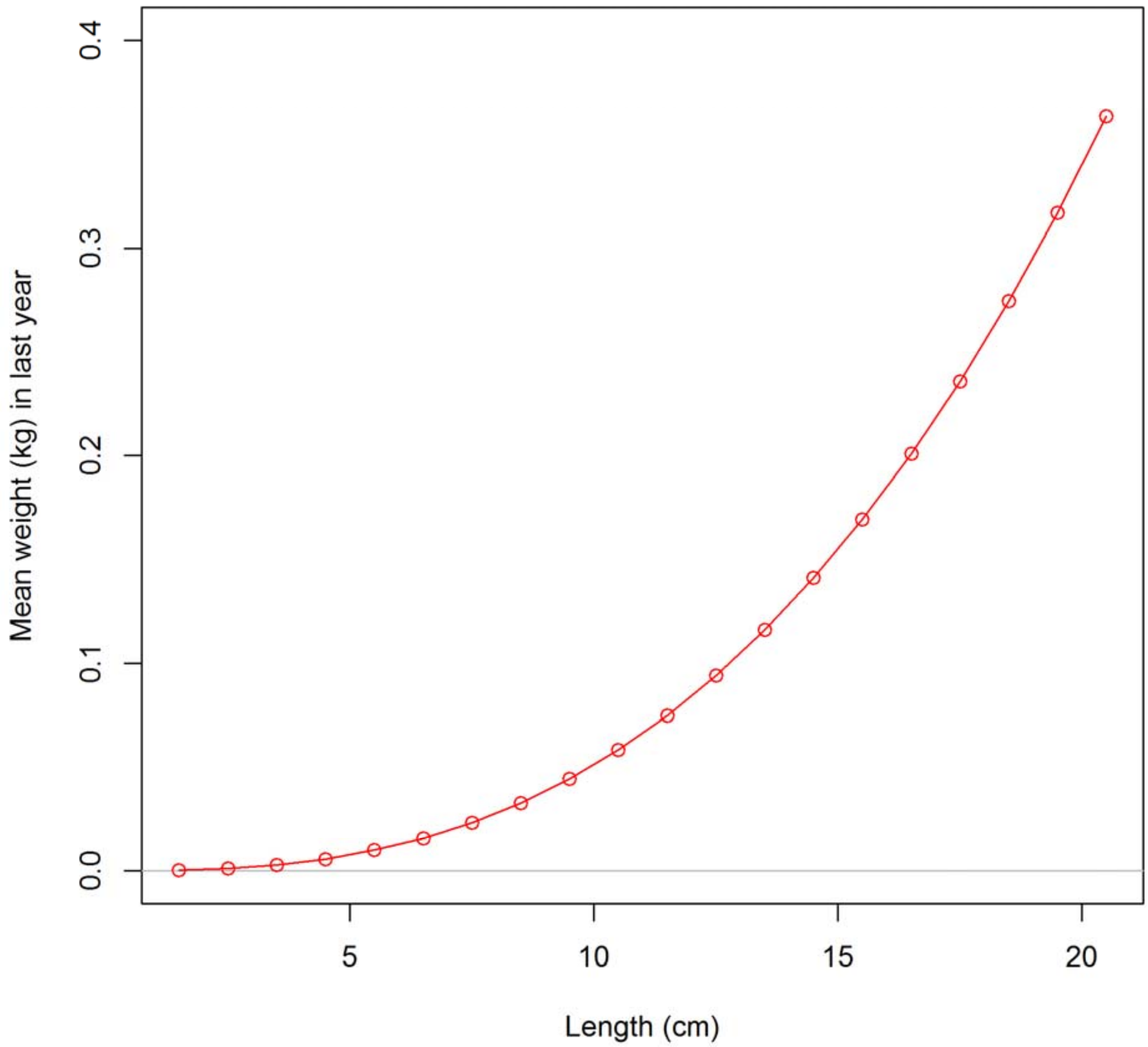


Appendix A5. Figure 22. Retrospective patterns in total biomass for the years 2000-2011 using the base case northern area KLAMZ model.

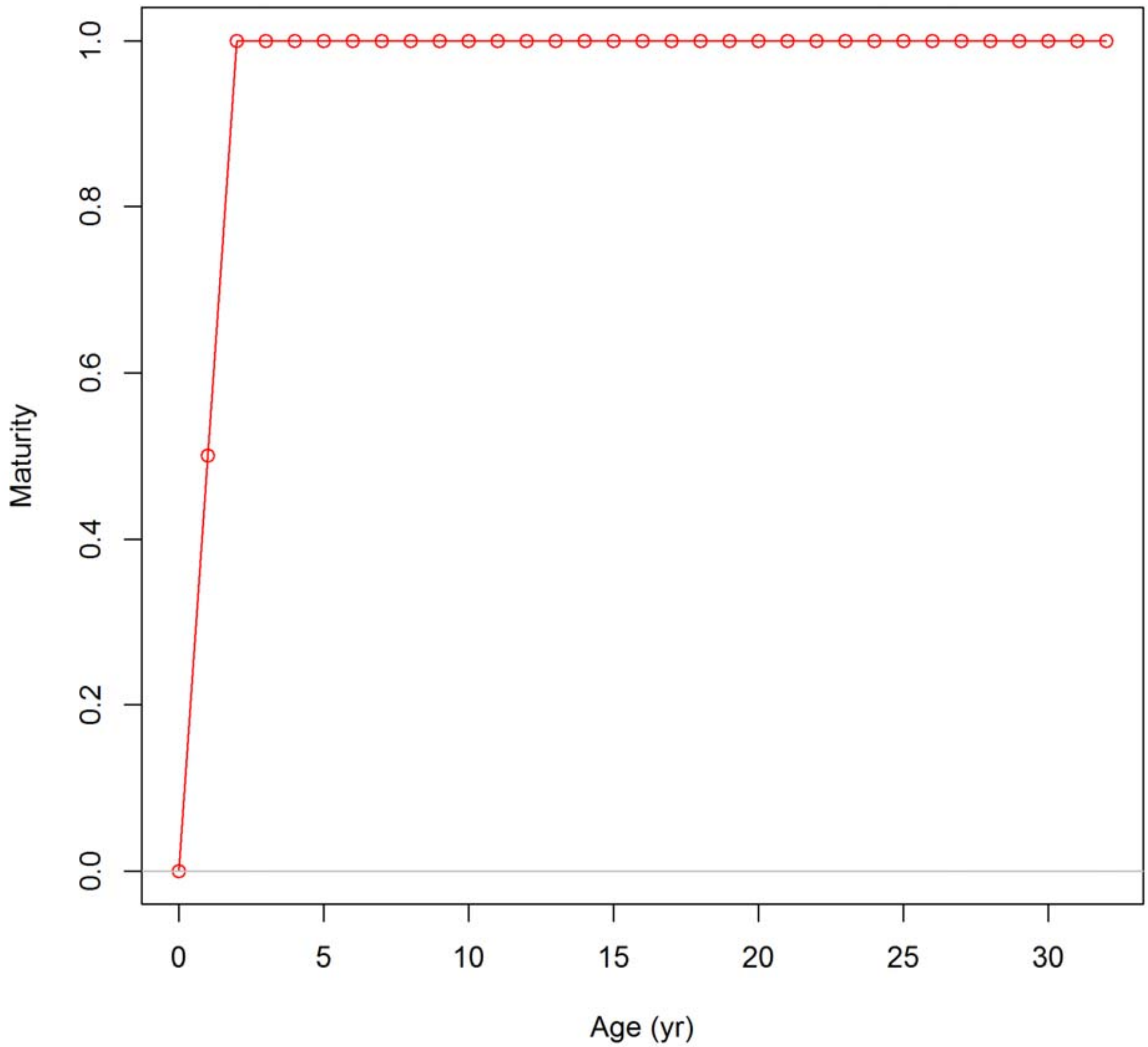
Appendix A6: SS3 diagnostics for the southern area

Plots created using the 'r4ss' package in R
Stock Synthesis version: SS−V3.24f
StartTime: Thu Dec 6 12:28:02 2012
Data_File: Surfclam_South−1.dat
Control_File: Surfclam_South−1.ctl

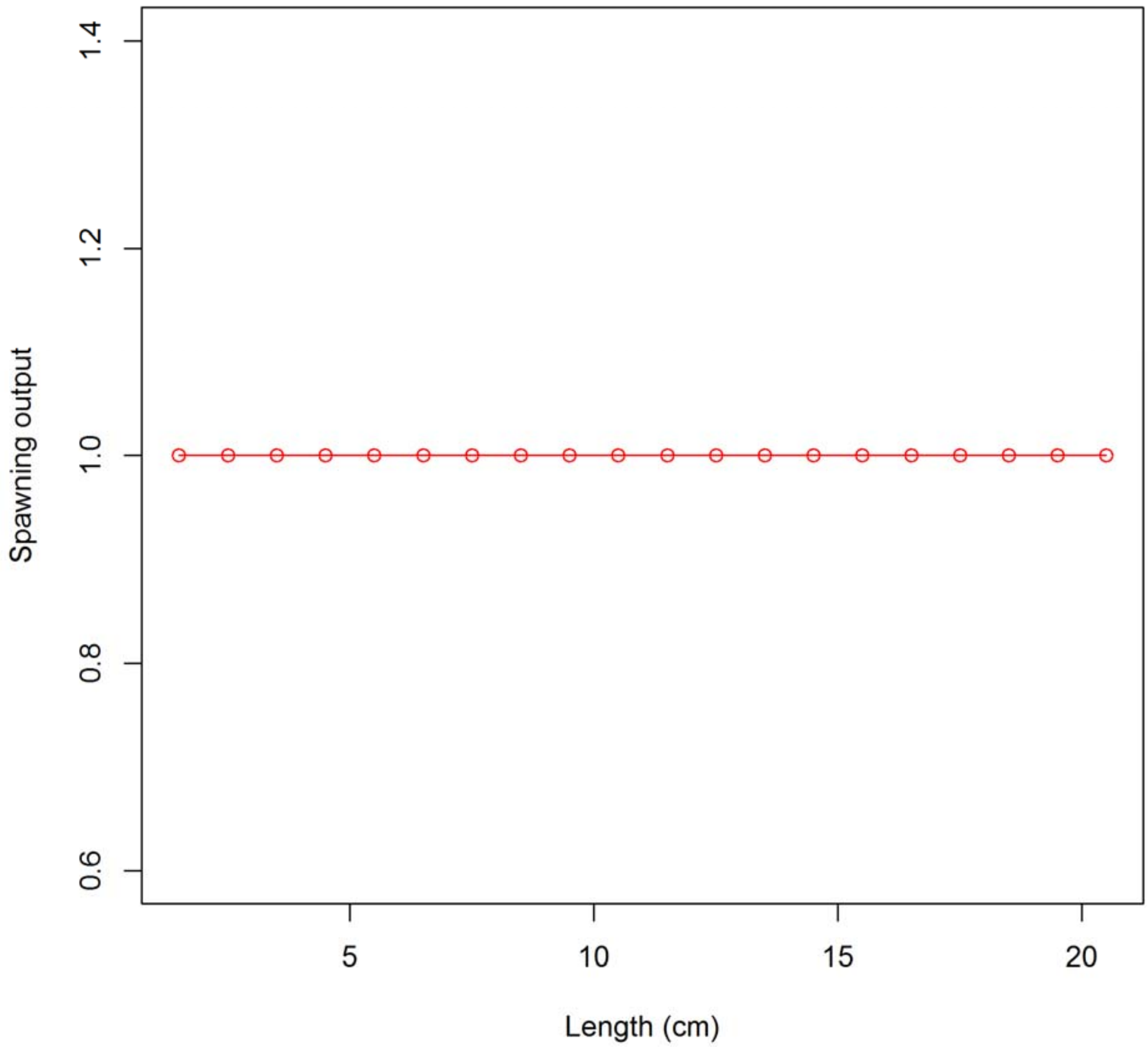


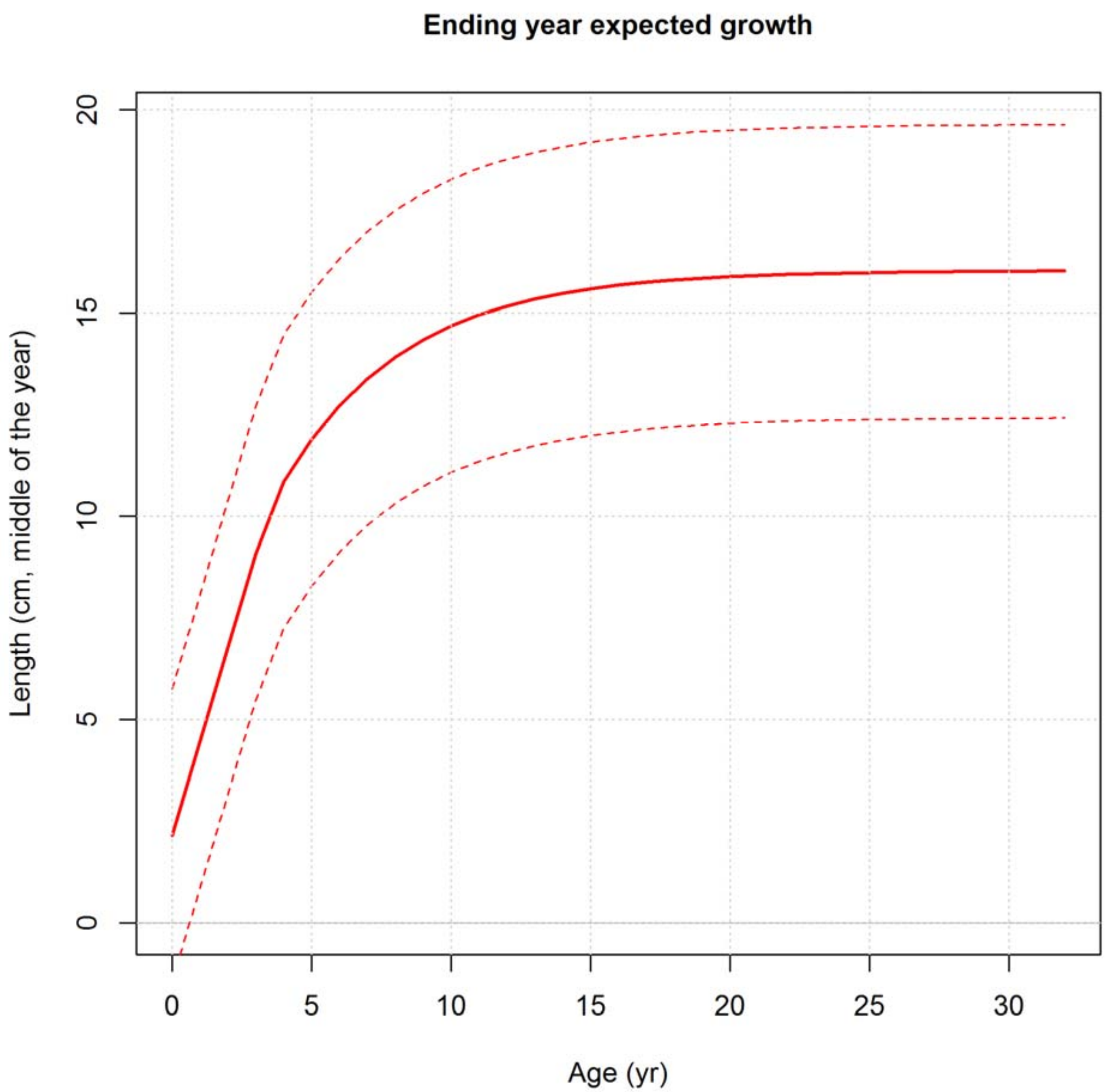


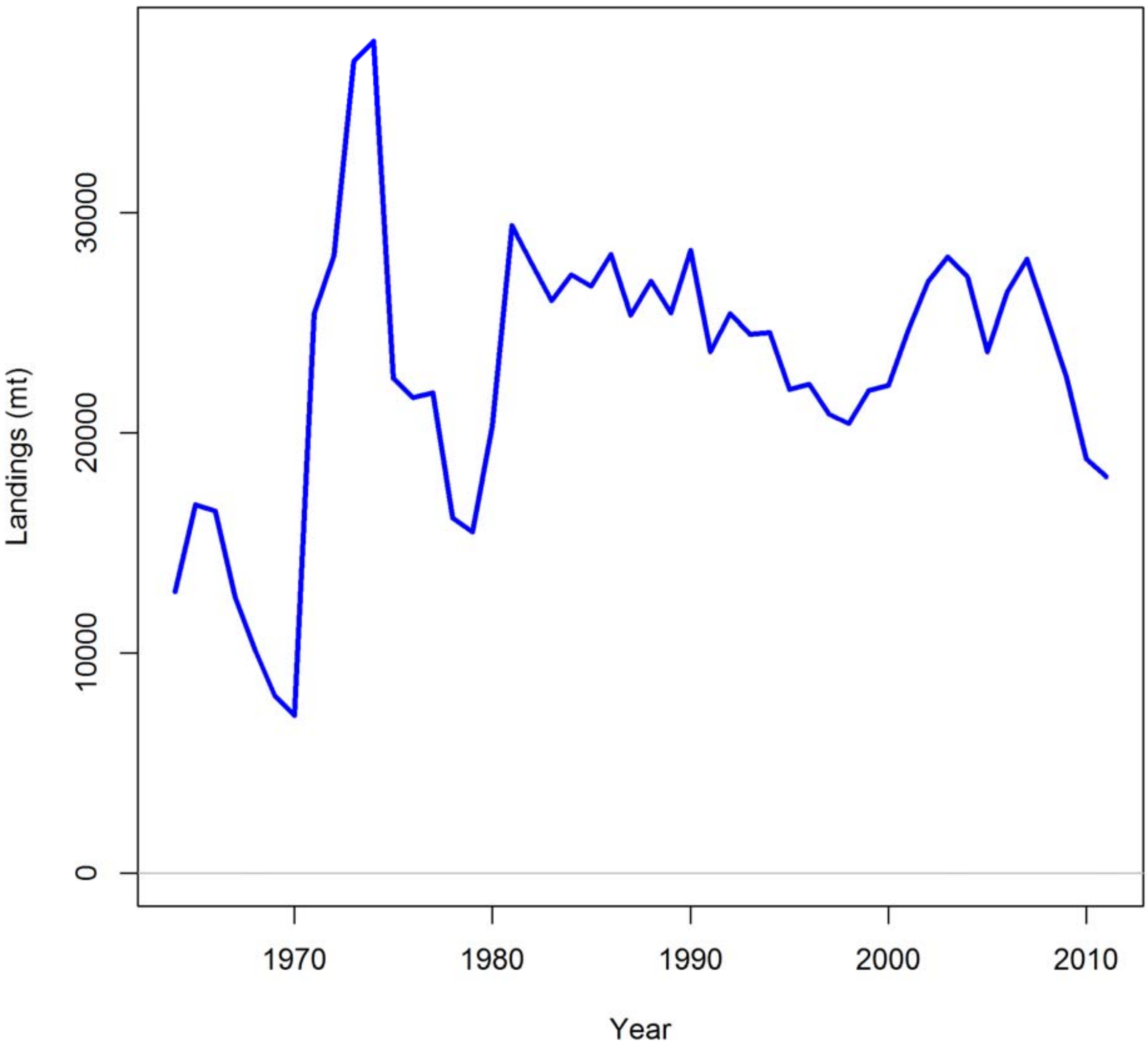
Mean weight (kg) in last year
0.0
0.1
0.2
0.3
0.4
5
10
15
20
Length (cm)



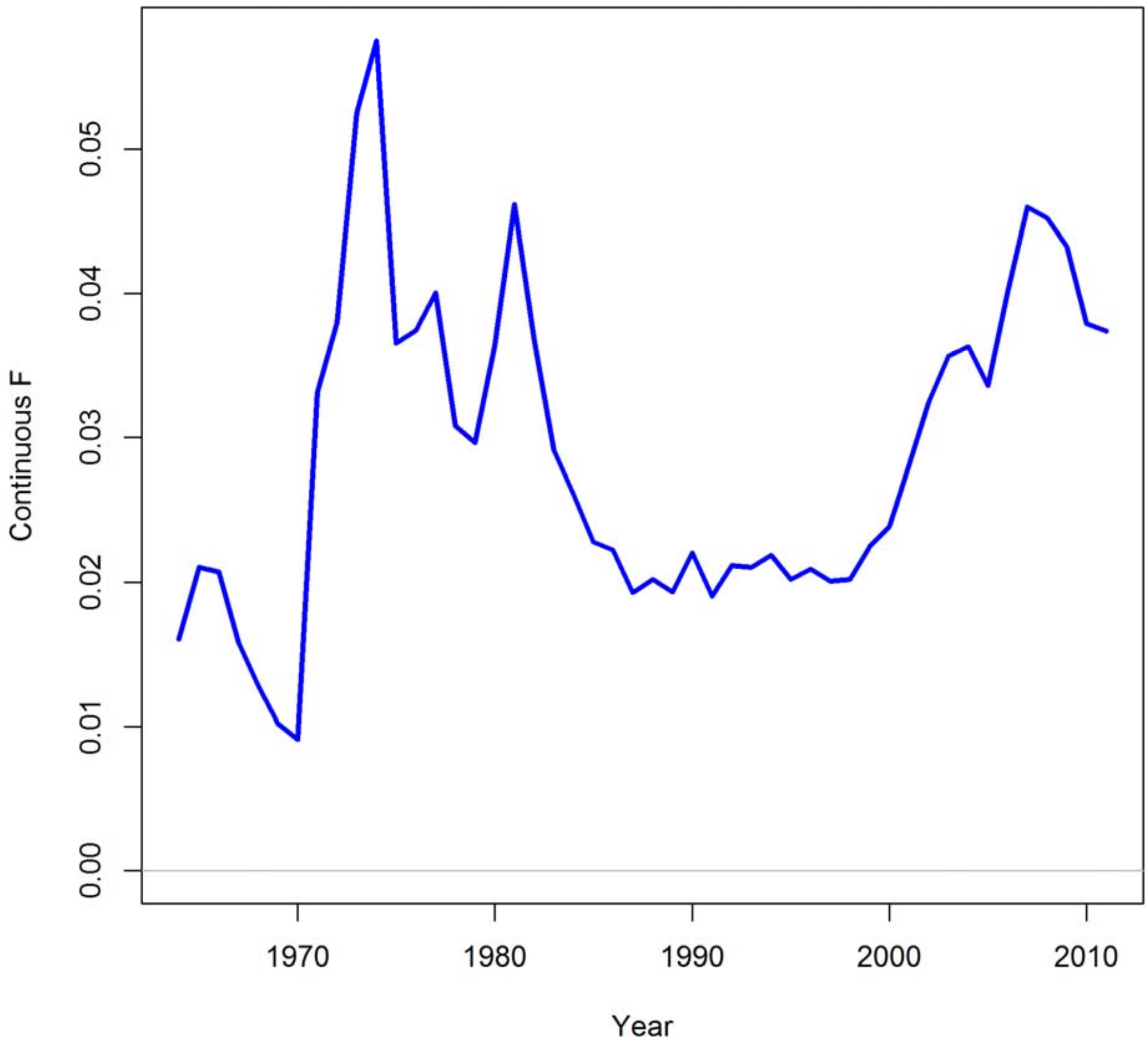
Maturity
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30
Age (yr)

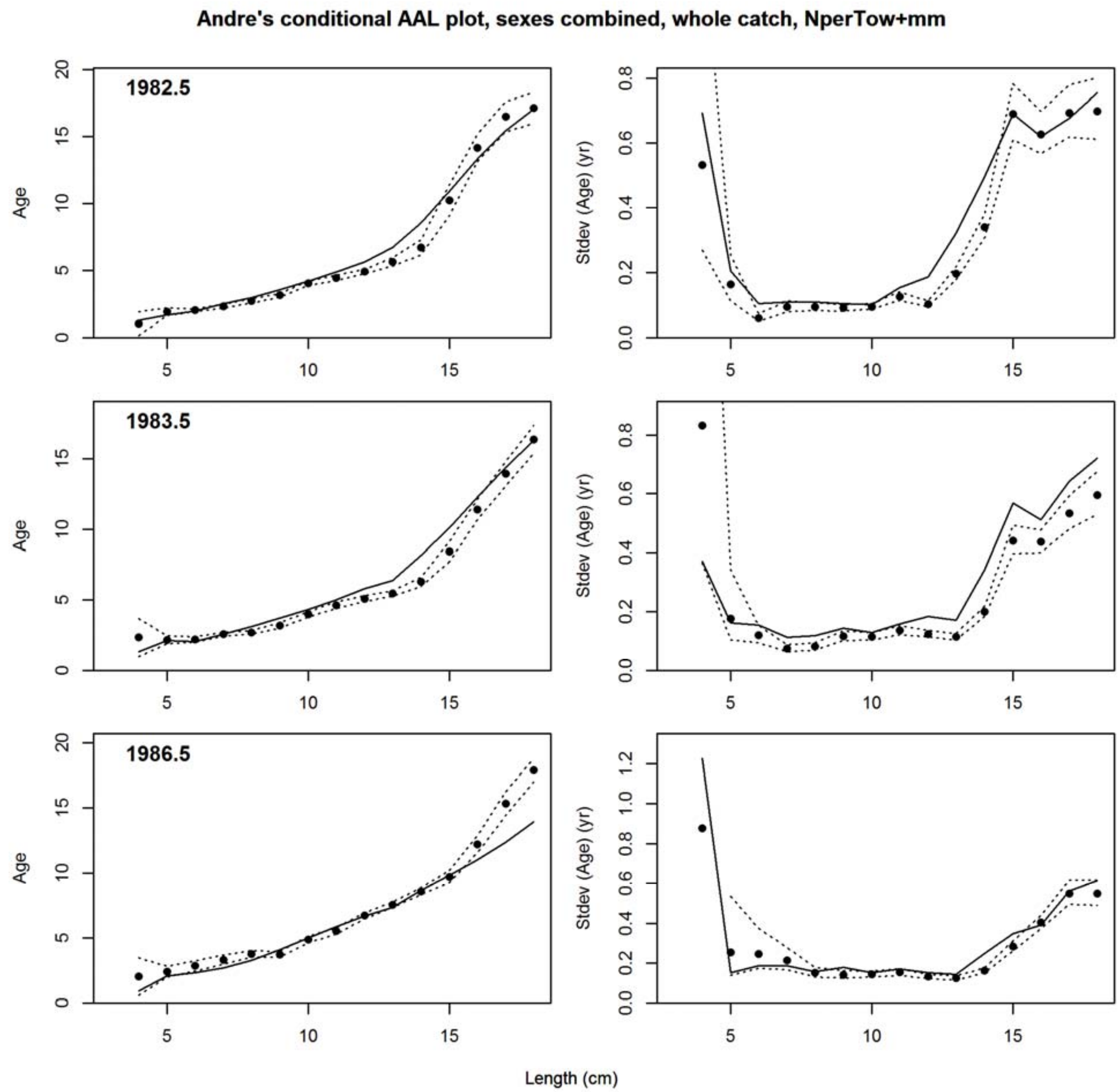

1.4
1.2
1.0
0.8
0.6
Spawning output
5
10
15
20
Length (cm)


Ending year expected growth
Length (cm, middle of the year)
0
5
10
15
20
0
5
10
15
20
25
30
Age (yr)



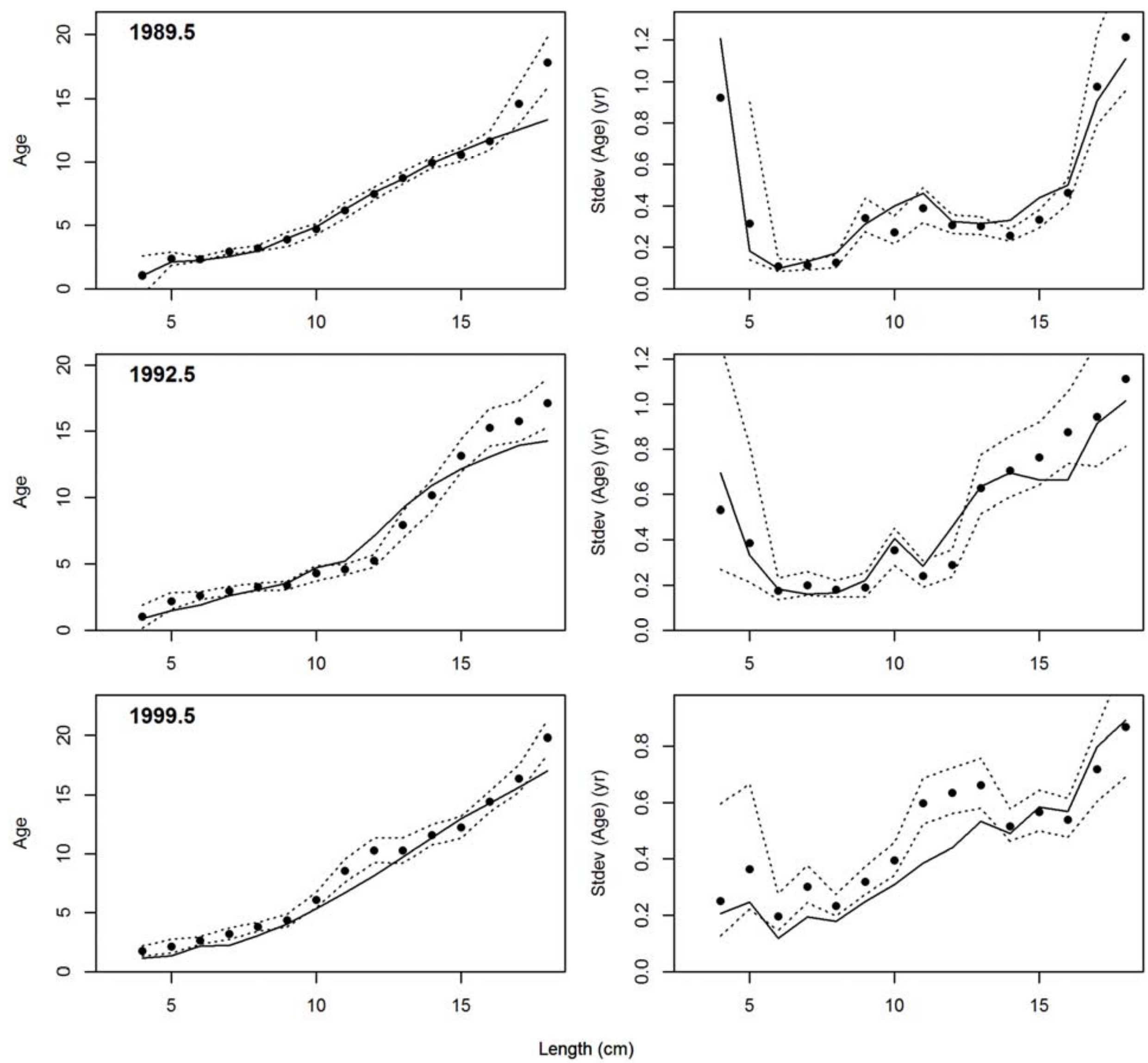
Landings (mt)
0
10000
20000
30000
1970
1980
1990
2000
2010
Year


Continuous F
0.00
0.01
0.02
0.03
0.04
0.05
1970
1980
1990
2000
2010
Year

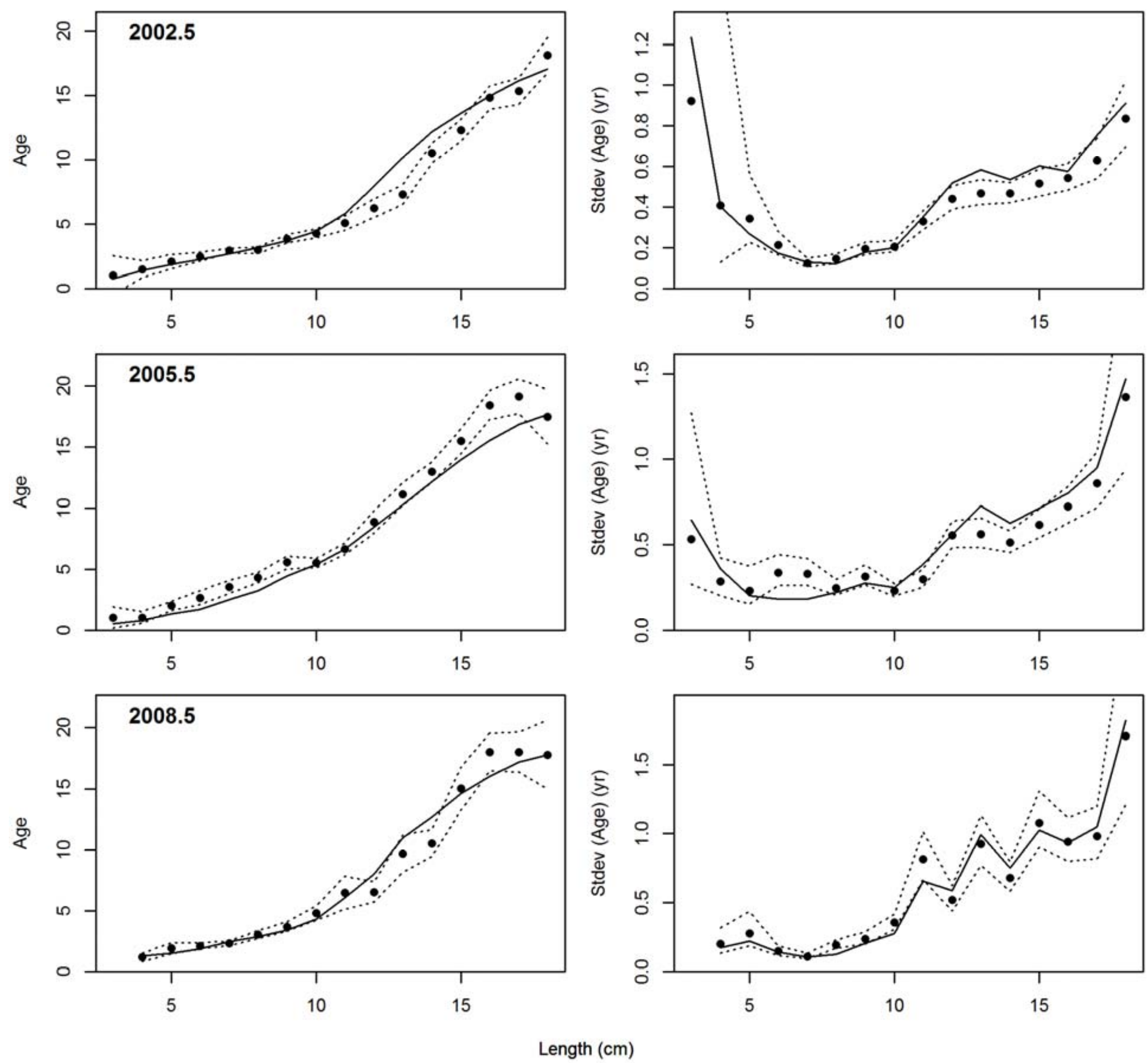


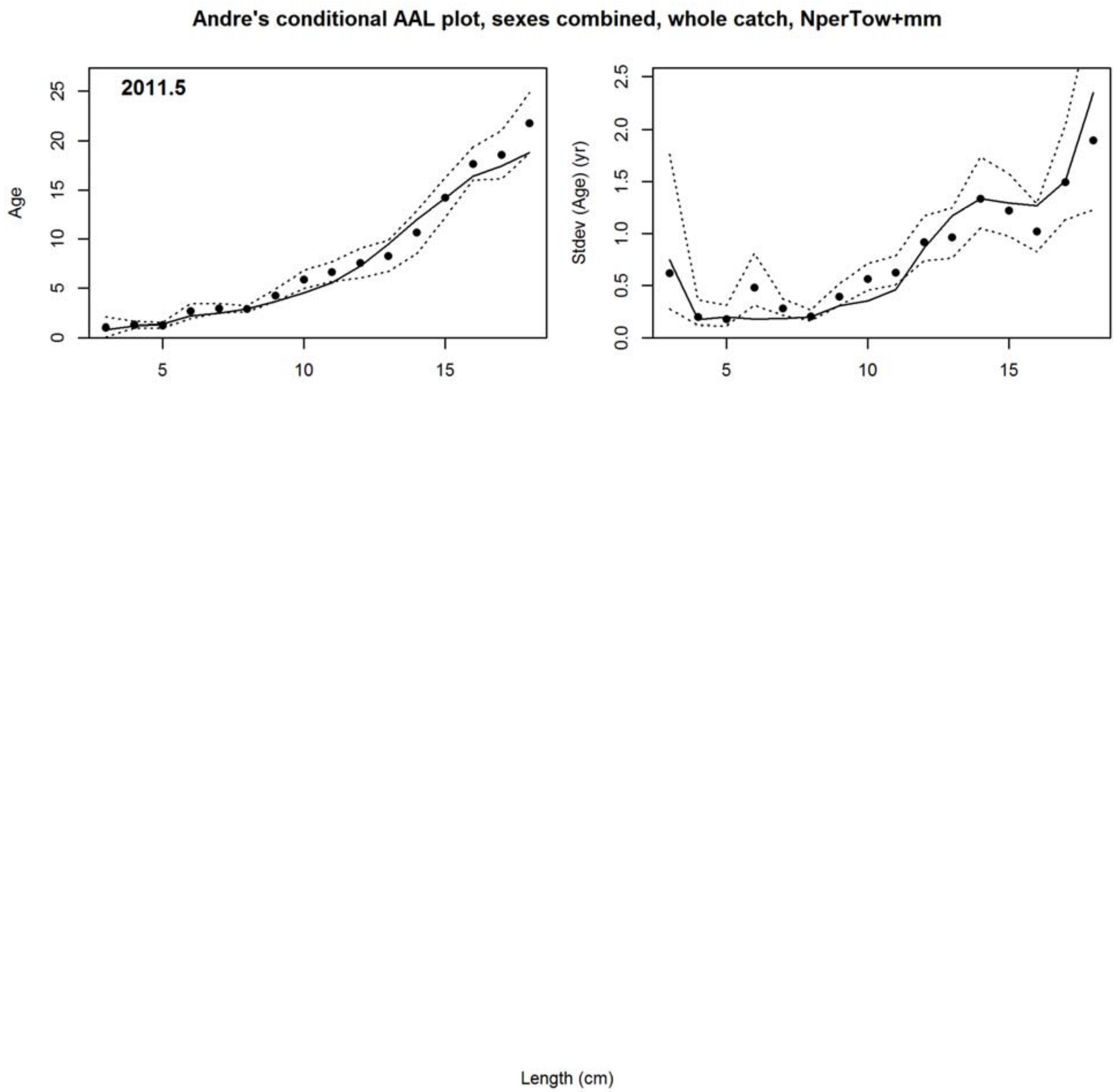
Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm
1982.5
1983.5
1986.5
Age
Stdev (Age) (yr)
Length (cm)

Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm



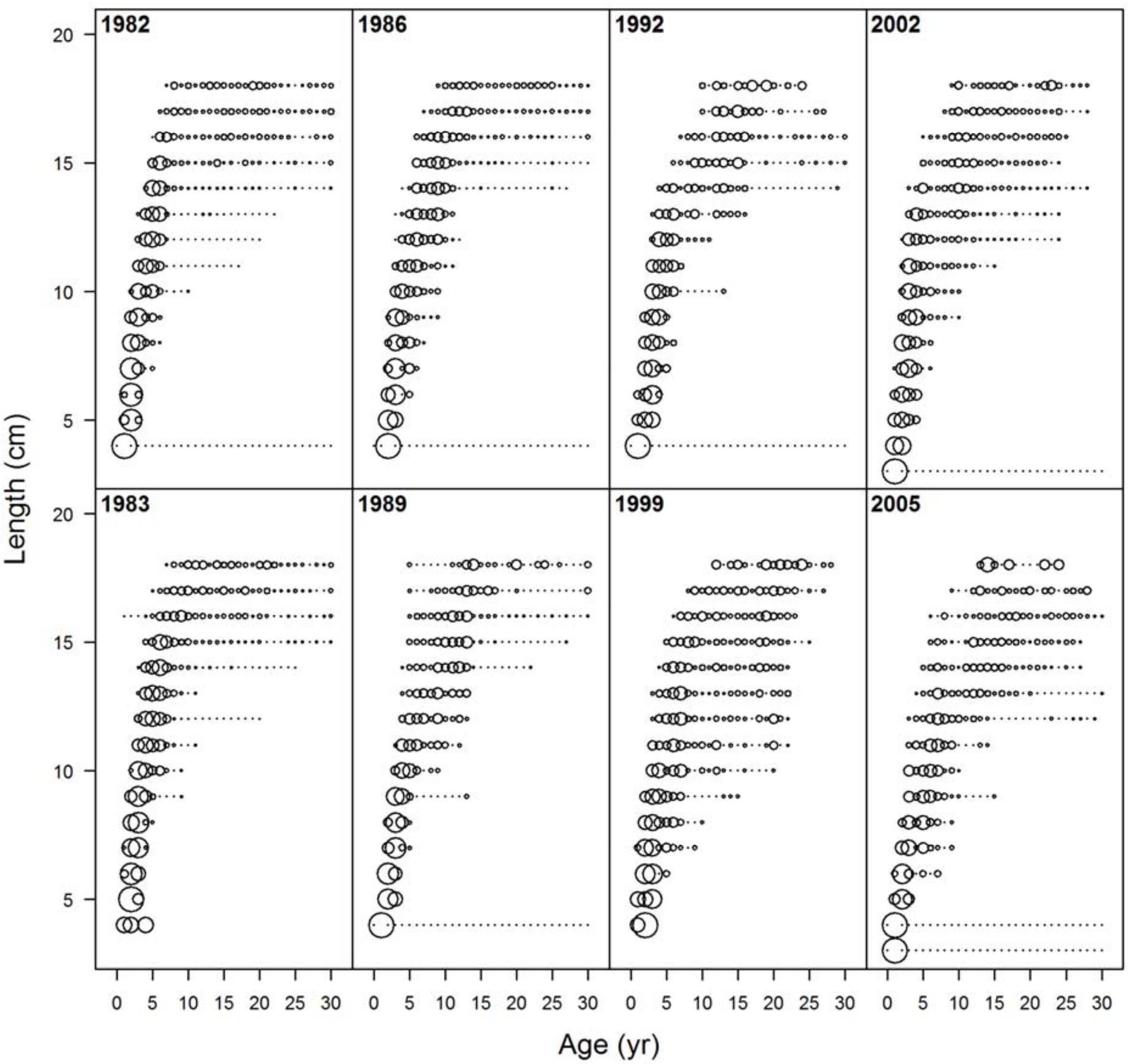
Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm



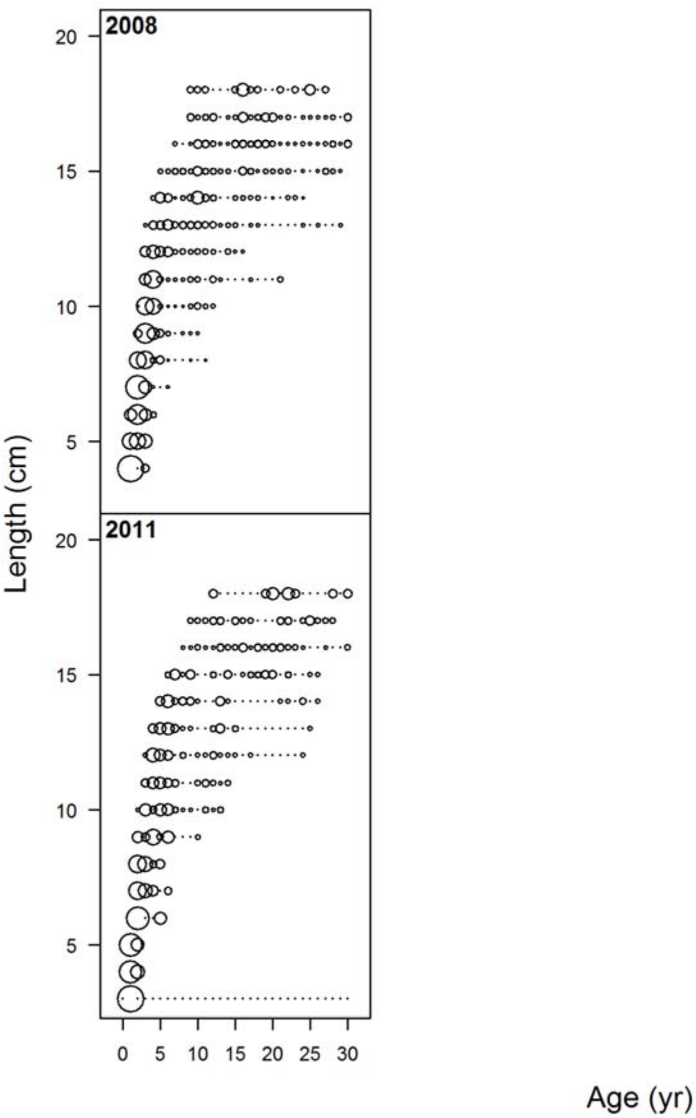


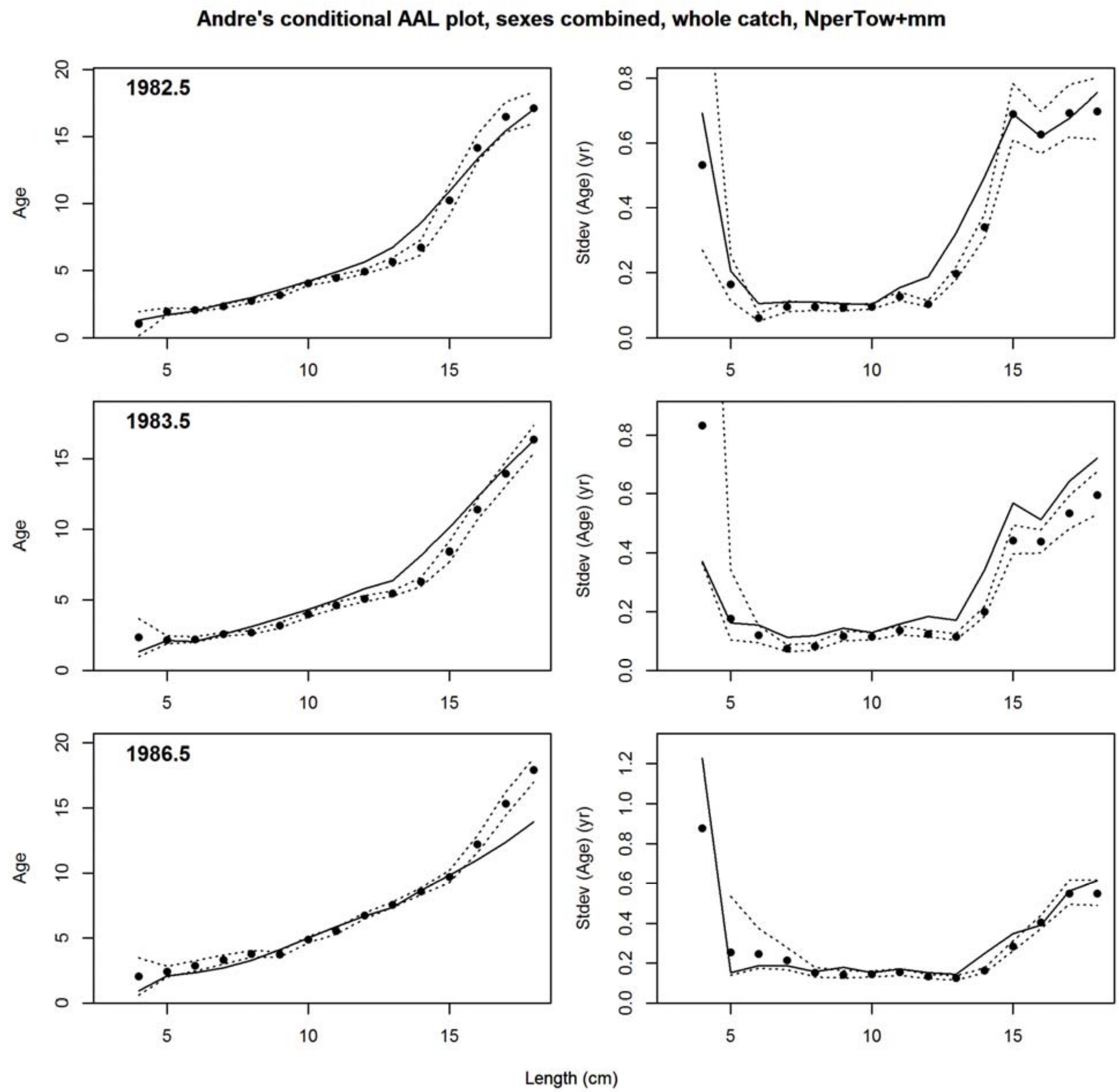
Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm
2011.5
Age
0
5
10
15
20
25
Stdev (Age) (yr)
0.0
0.5
1.0
1.5
2.0
2.5
5
10
15
Length (cm)

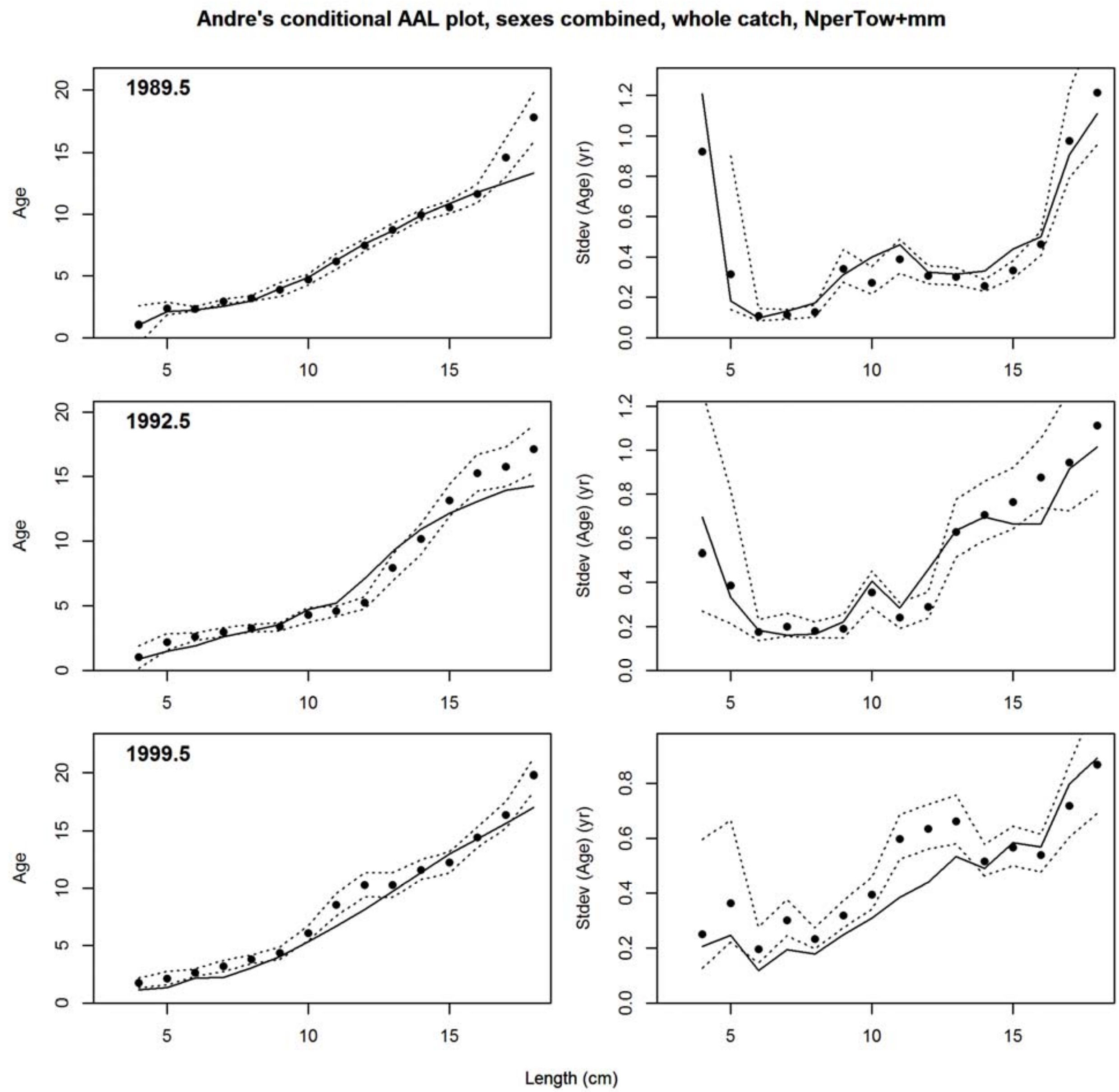
conditional age-at-length data, sexes combined, whole catch, NperTow+mm (max=1



conditional age-at-length data, sexes combined, whole catch, NperTow+mm (max=1

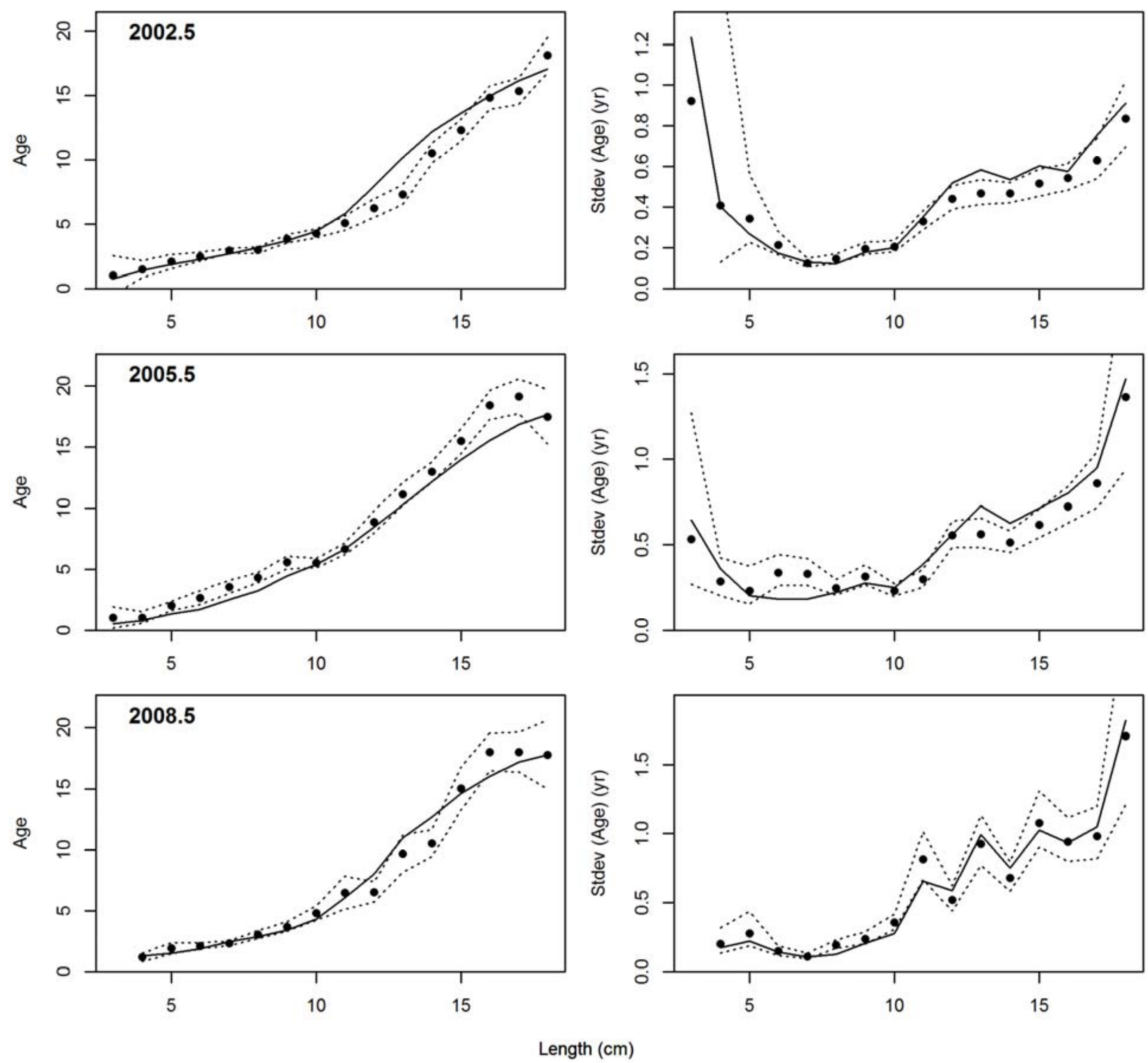



Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm
1982.5
1983.5
1986.5
Age
Stdev (Age) (yr)
Length (cm)

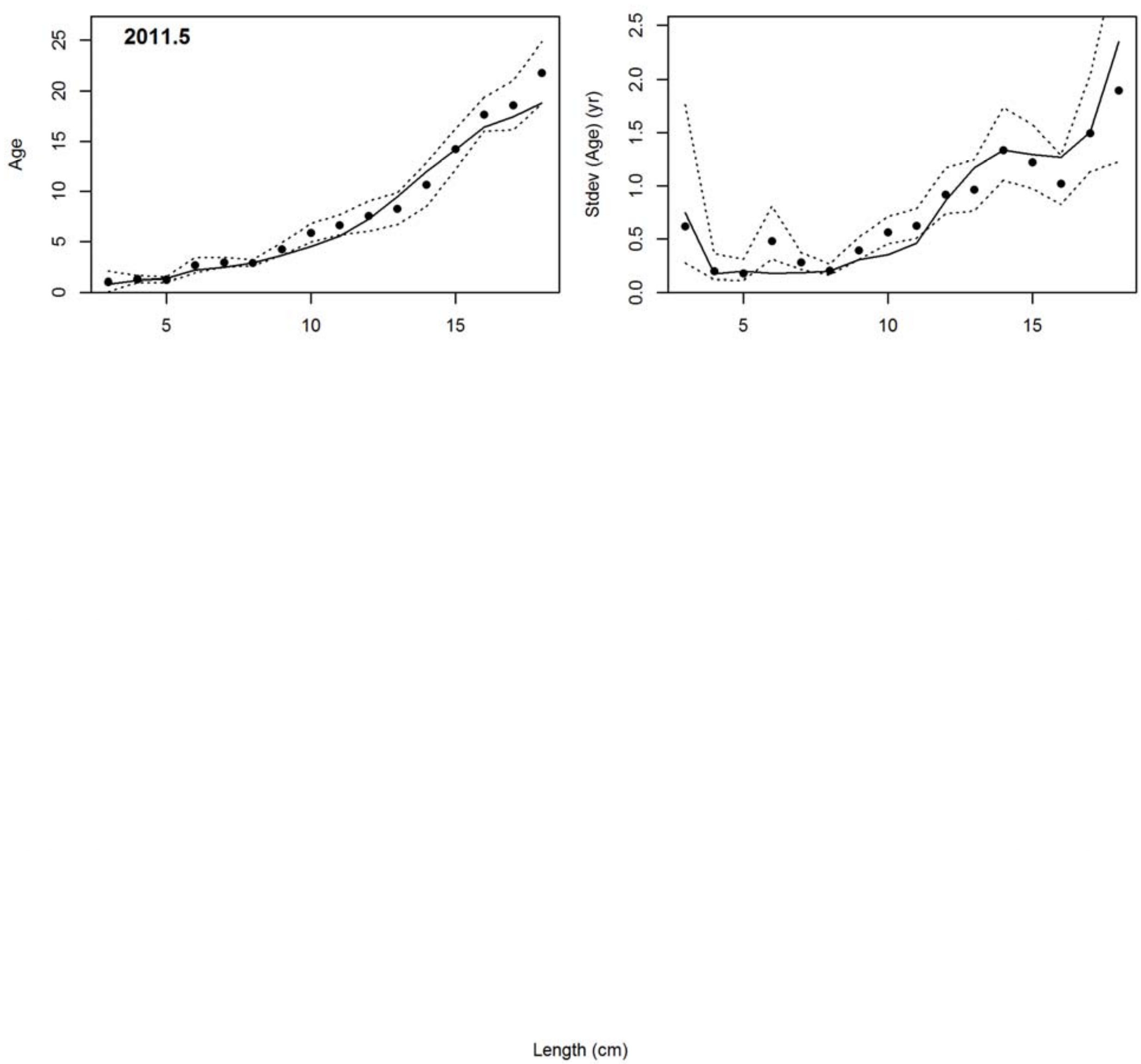


Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm
1989.5
1992.5
1999.5
Age
Stdev (Age) (yr)
Length (cm)

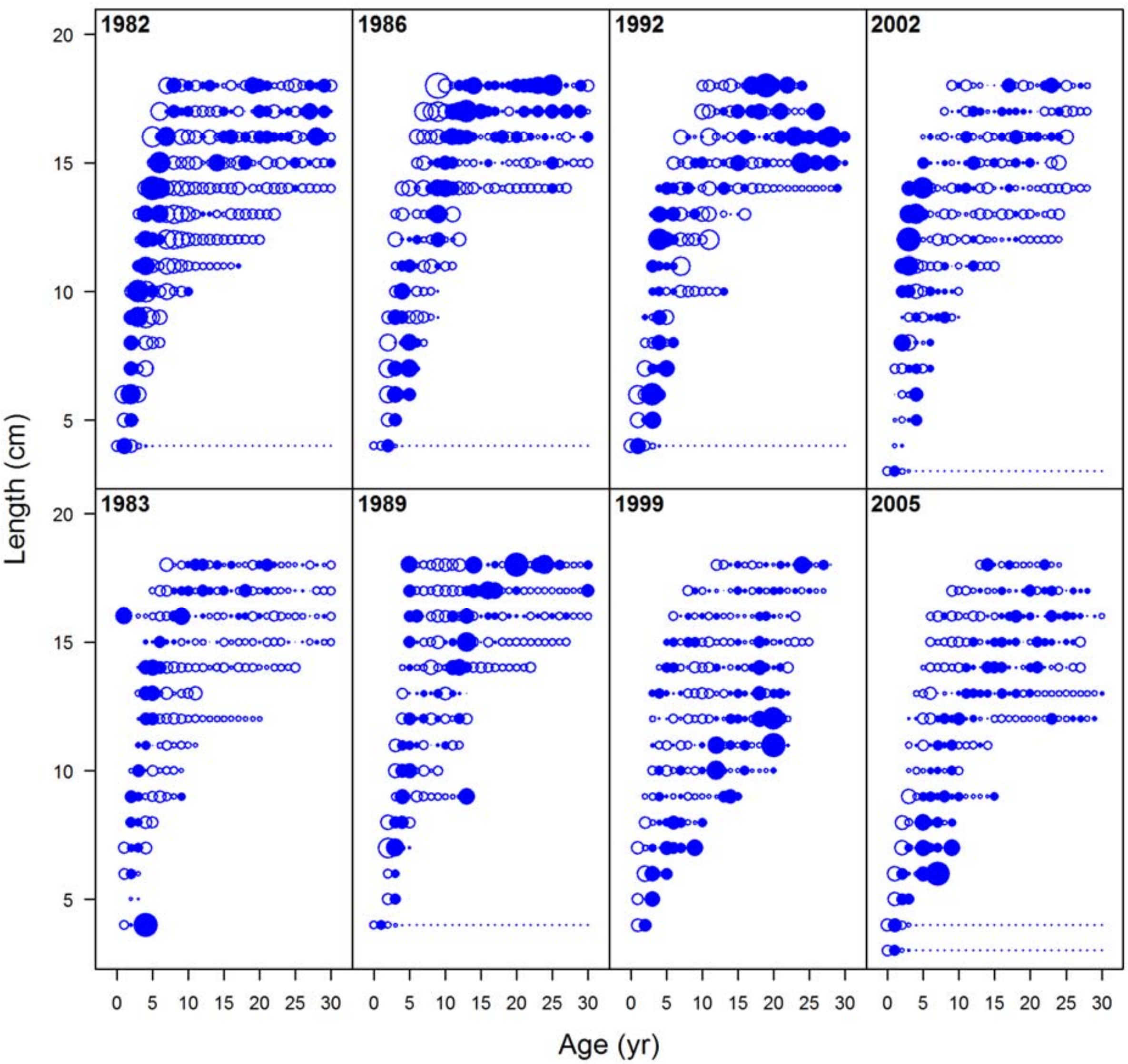
Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm



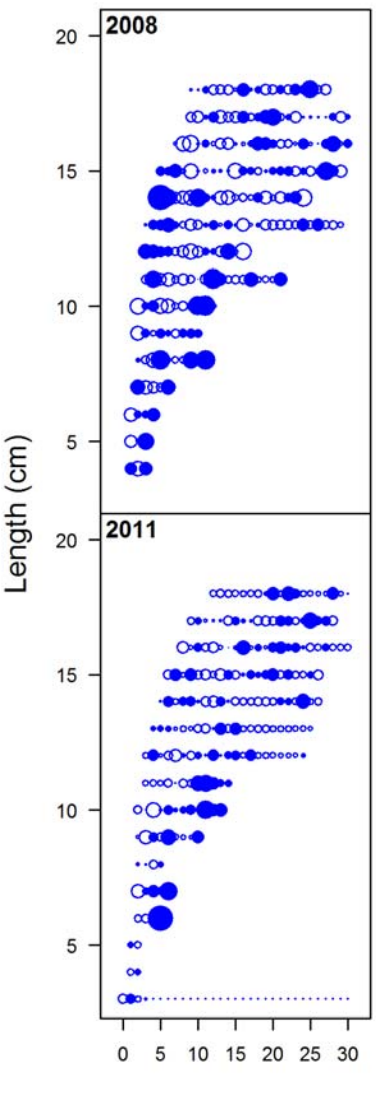
Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm



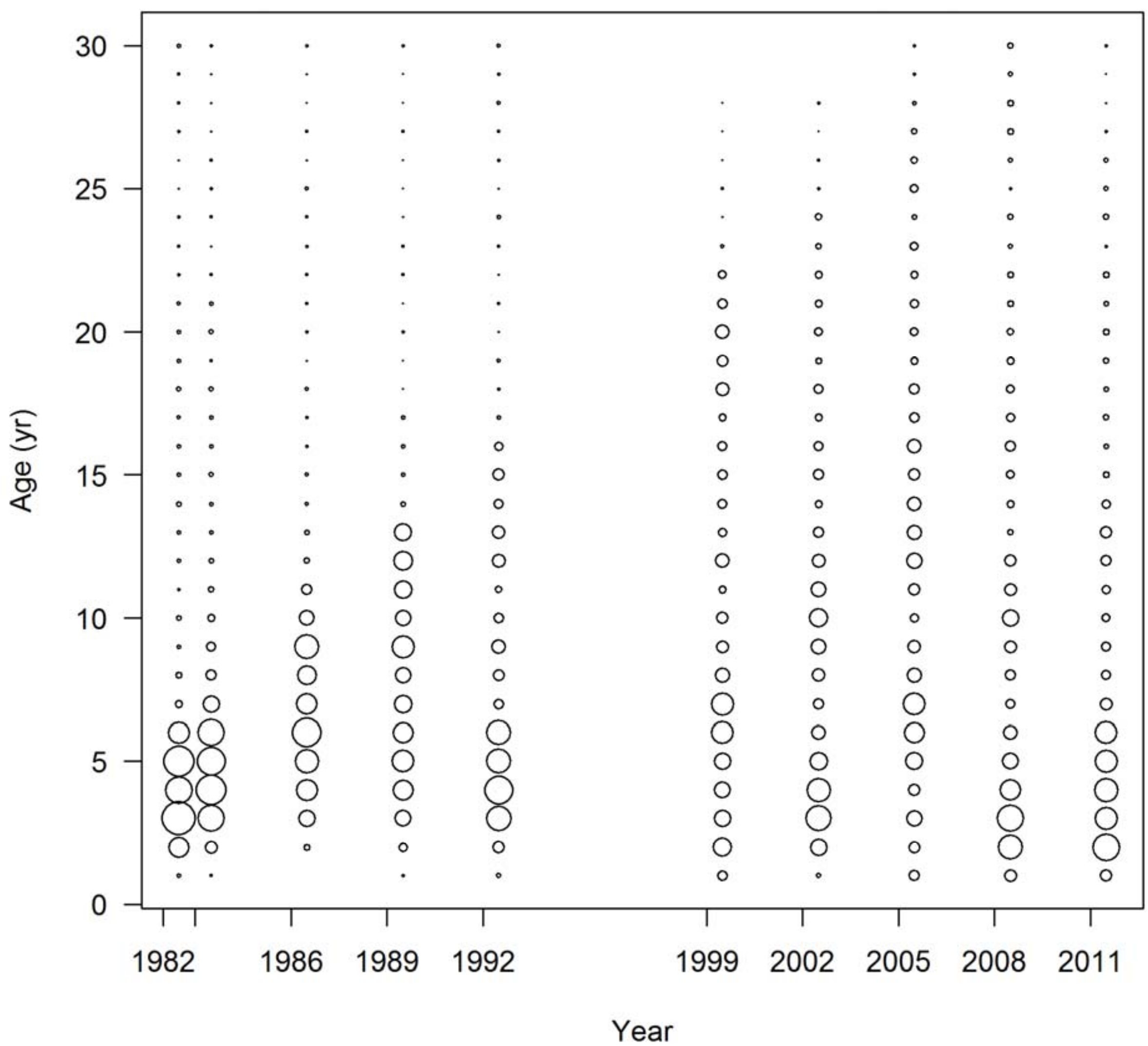
Pearson residuals, sexes combined, whole catch, NperTow+mm (max=10.83)

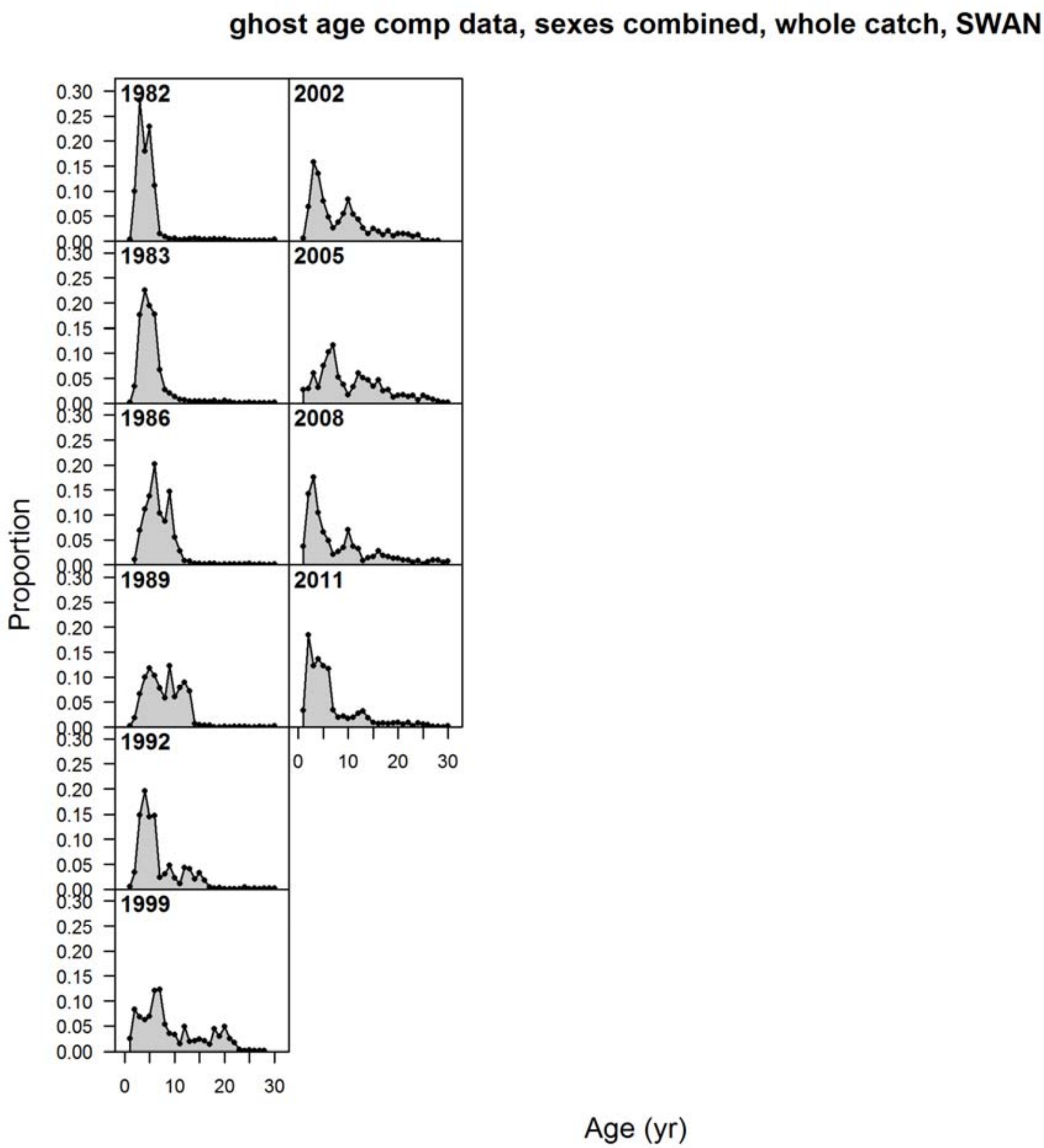


Pearson residuals, sexes combined, whole catch, NperTow+mm (max=10.83)

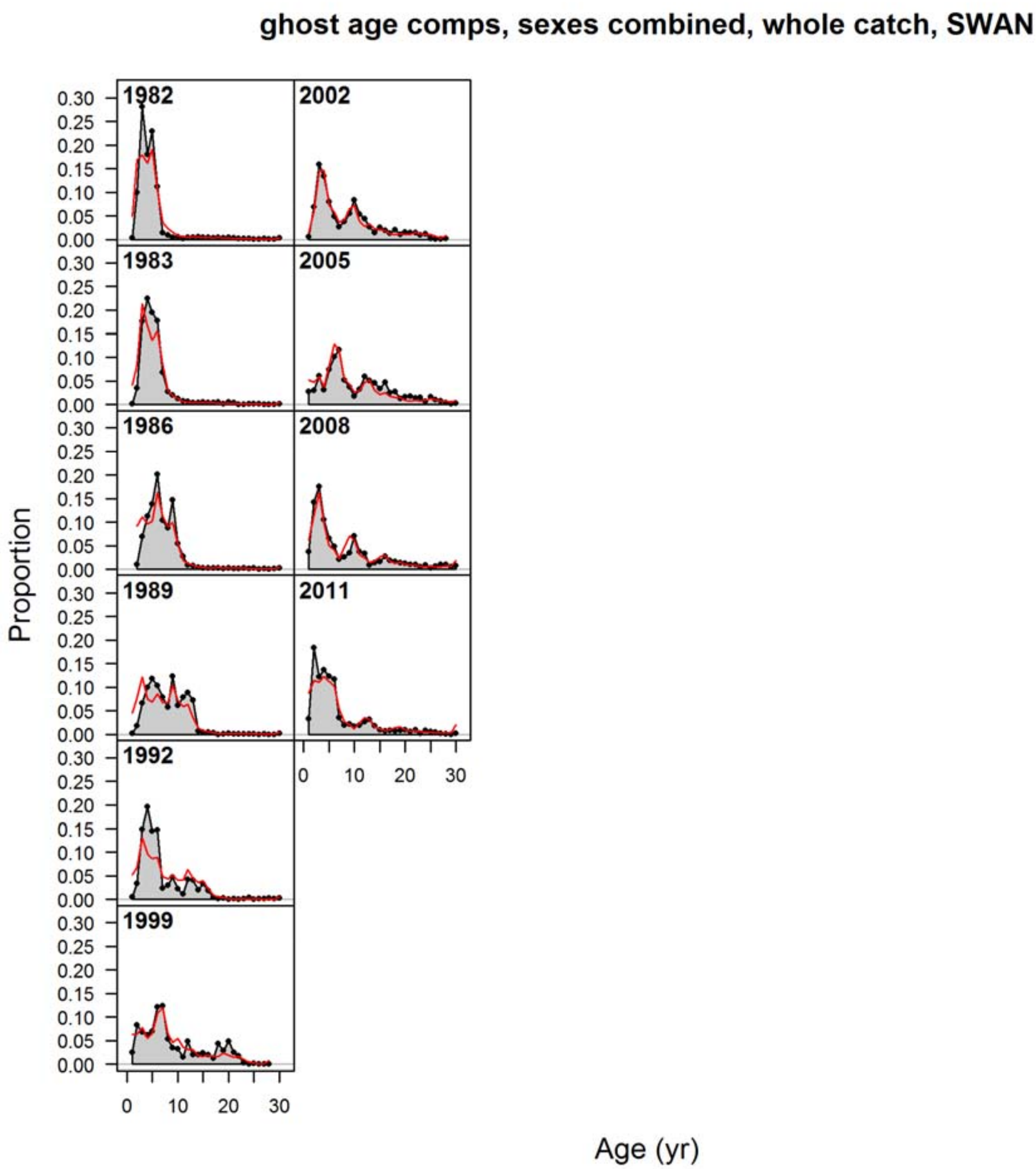


ghost age comp data, sexes combined, whole catch, SWAN (max=0.28)



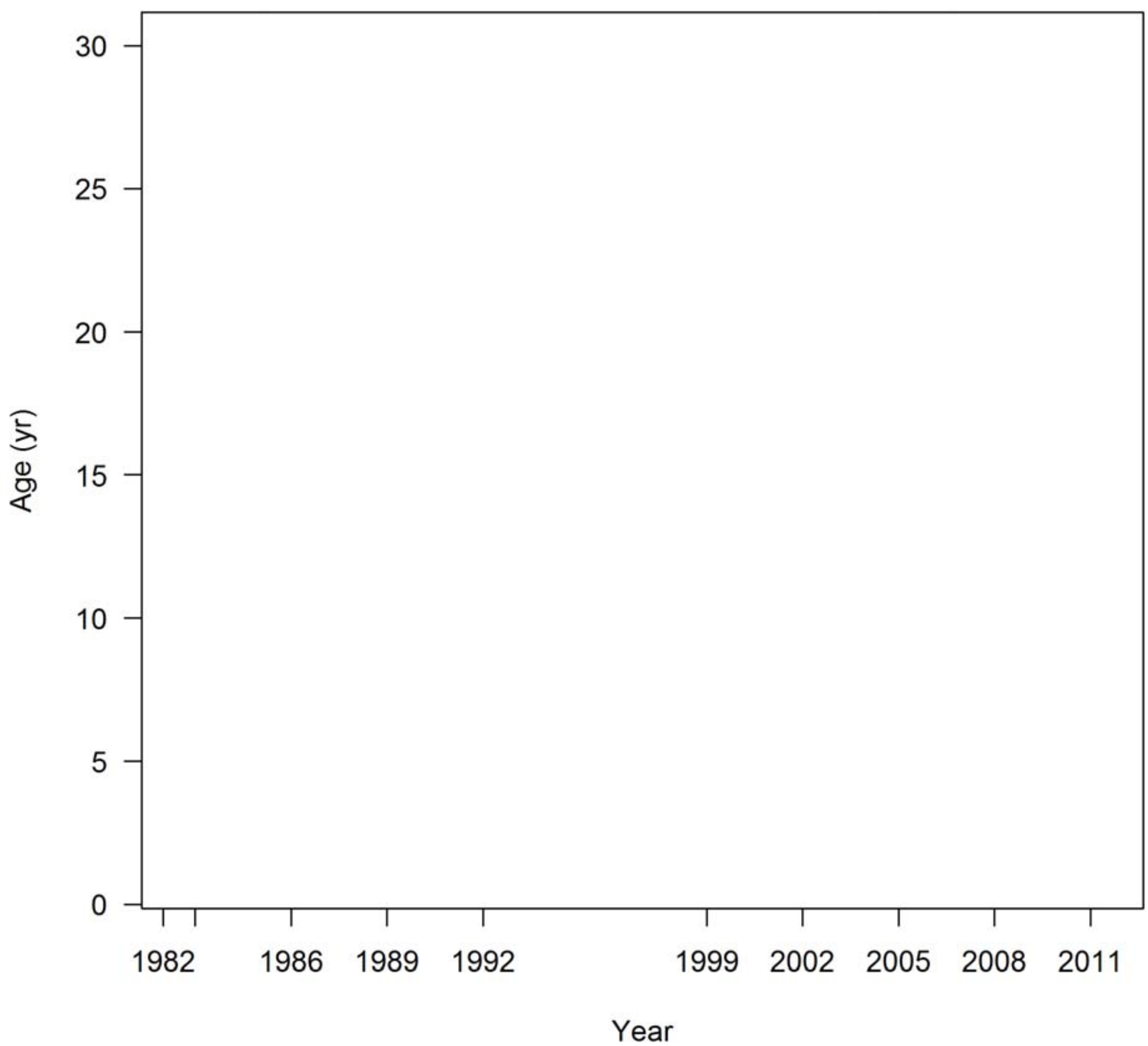


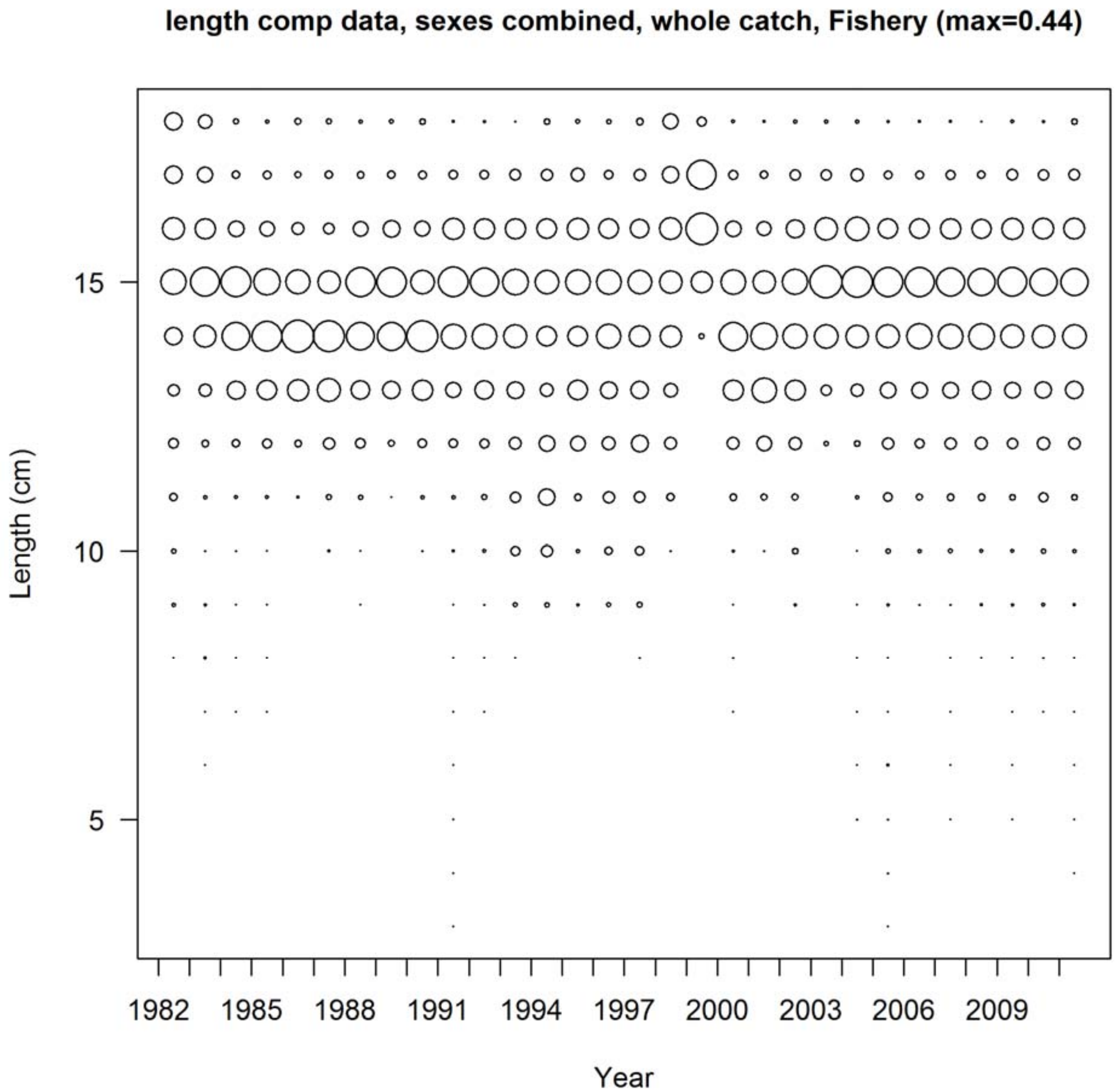
ghost age comp data, sexes combined, whole catch, SWAN
1982
2002
1983
2005
1986
2008
1989
2011
1992
1999
Proportion
Age (yr)



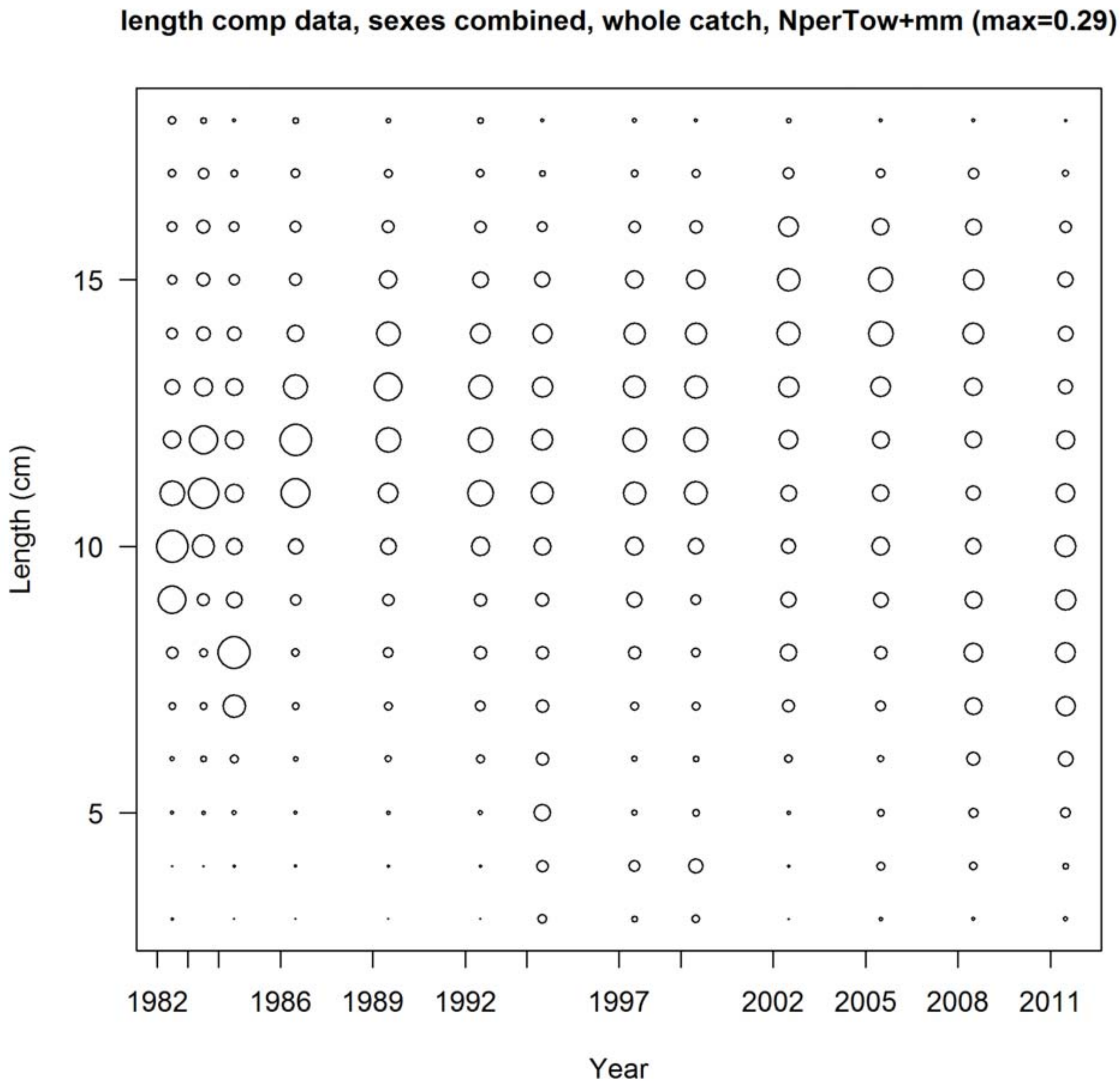
ghost age comps, sexes combined, whole catch, SWAN
Proportion
Age (yr)
1982
2002
1983
2005
1986
2008
1989
2011
1992
1999
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30

Pearson residuals, sexes combined, whole catch, SWAN (max=NA)

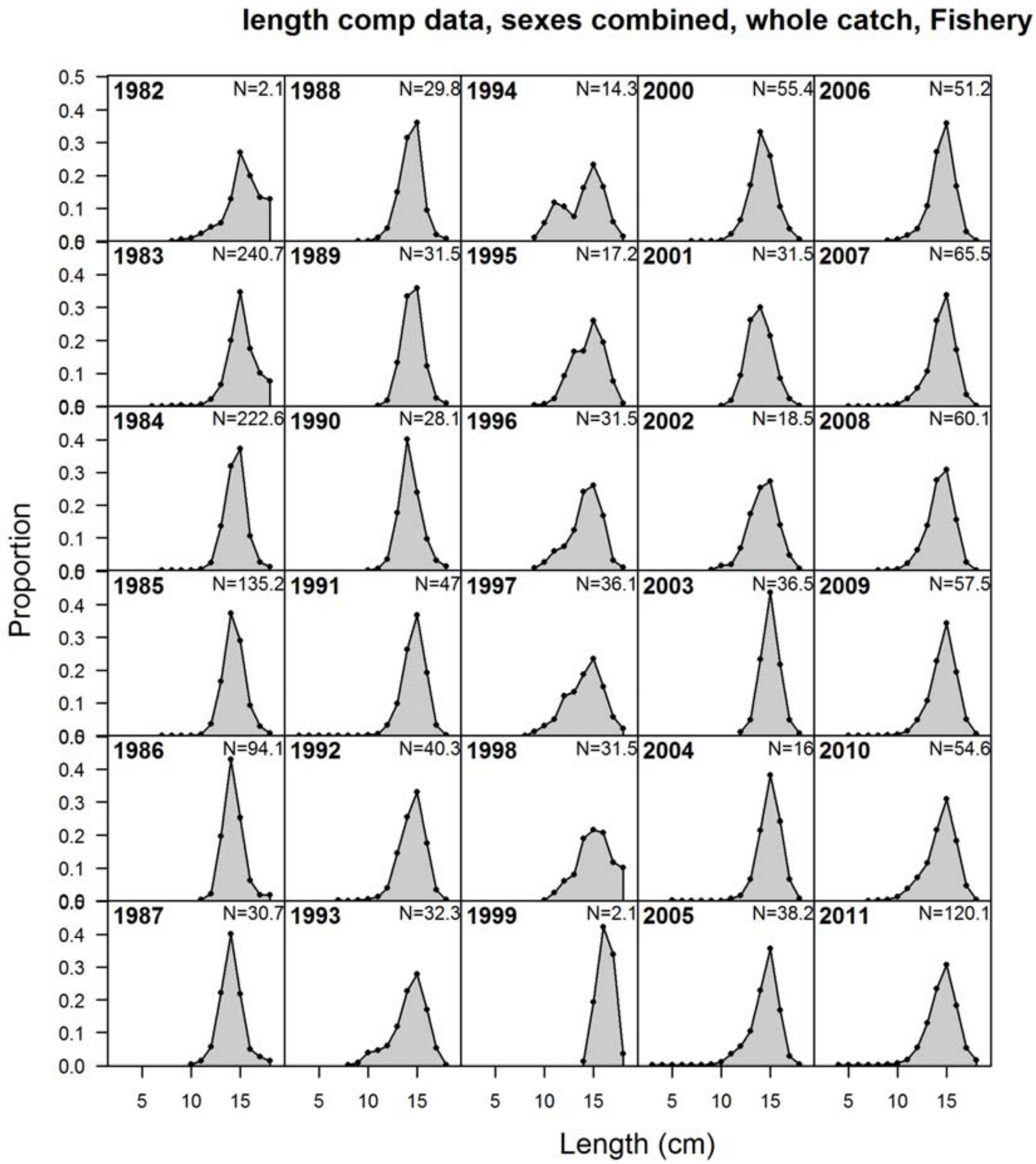




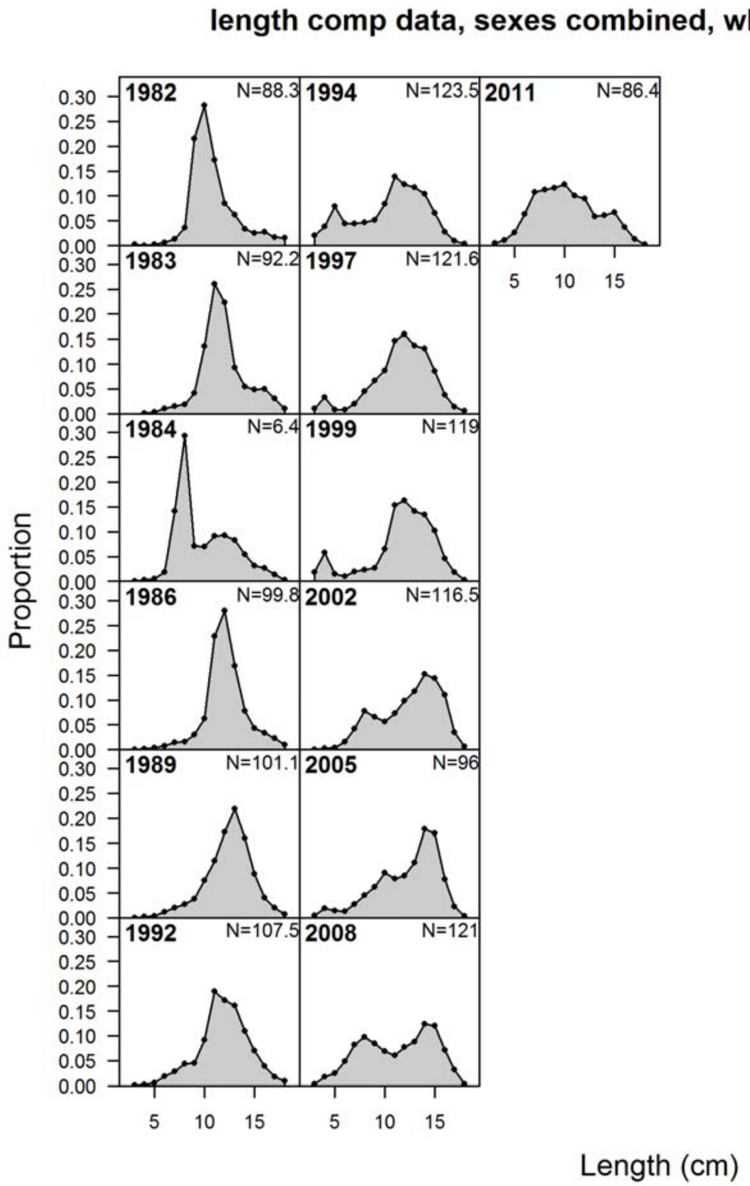
length comp data, sexes combined, whole catch, Fishery (max=0.44)
Length (cm)
15
10
5
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
Year



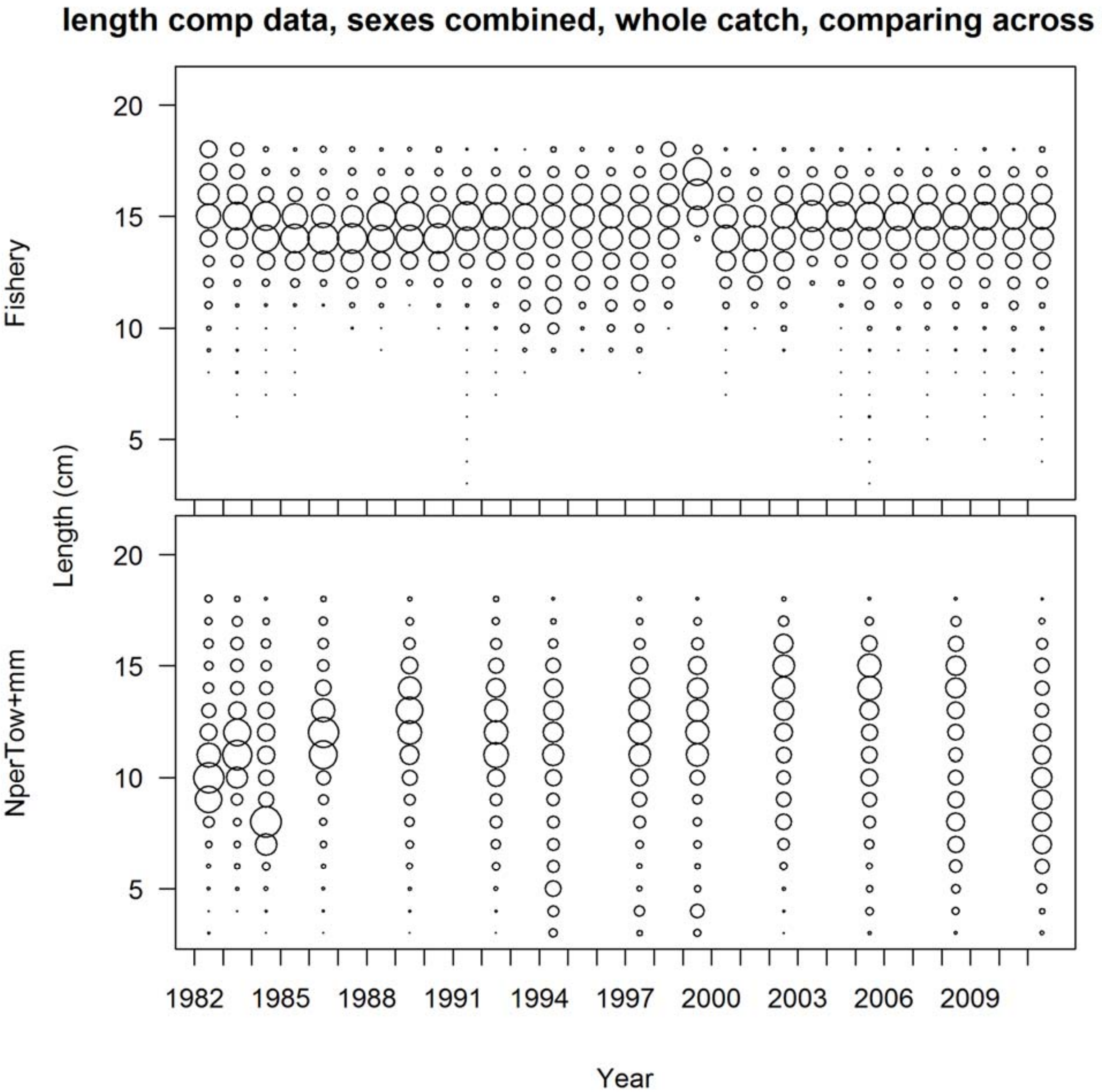
length comp data, sexes combined, whole catch, NperTow+mm (max=0.29)
Length (cm)
15
10
5
1982
1986
1989
1992
1997
2002
2005
2008
2011
Year



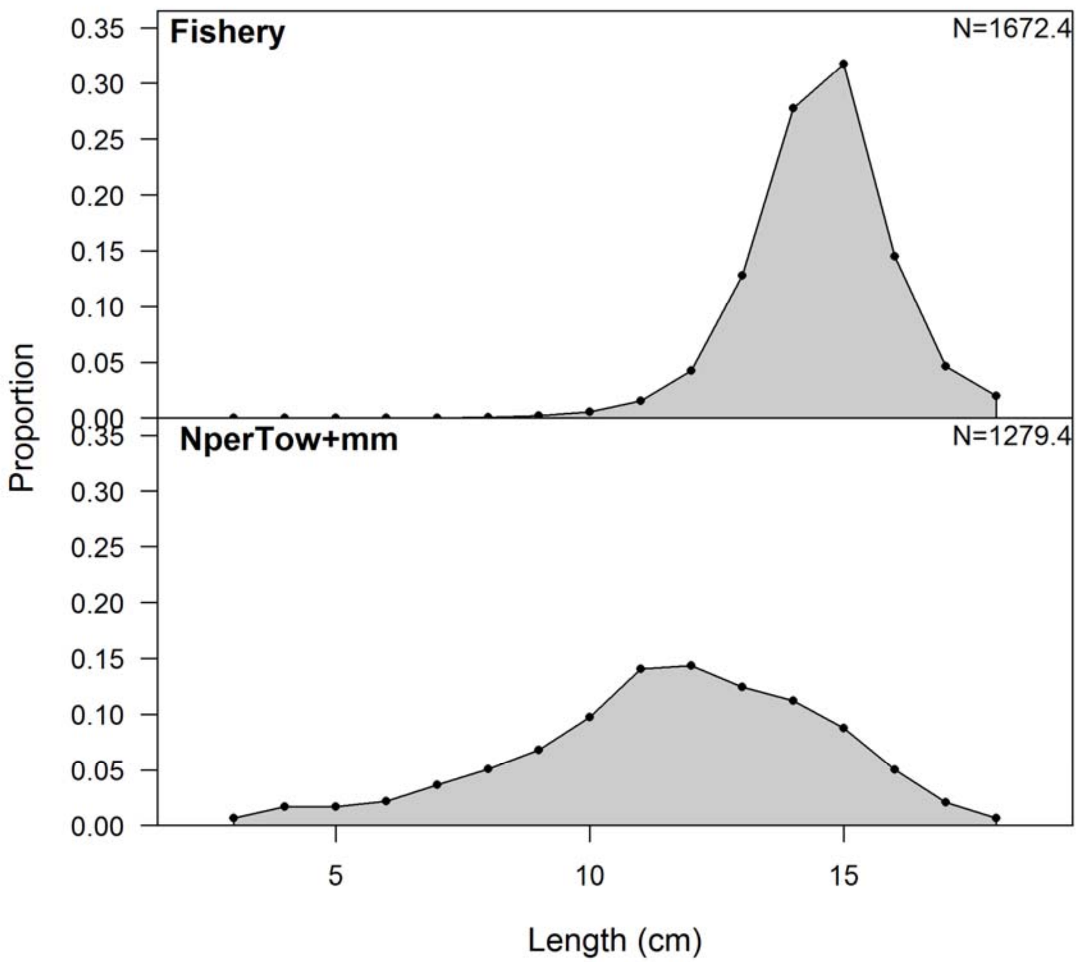
length comp data, sexes combined, whole catch, Fishery
1982 N=2.1
1988 N=29.8
1994 N=14.3
2000 N=55.4
2006 N=51.2
1983 N=240.7
1989 N=31.5
1995 N=17.2
2001 N=31.5
2007 N=65.5
1984 N=222.6
1990 N=28.1
1996 N=31.5
2002 N=18.5
2008 N=60.1
1985 N=135.2
1991 N=47
1997 N=36.1
2003 N=36.5
2009 N=57.5
1986 N=94.1
1992 N=40.3
1998 N=31.5
2004 N=16
2010 N=54.6
1987 N=30.7
1993 N=32.3
1999 N=2.1
2005 N=38.2
2011 N=120.1
Proportion
Length (cm)

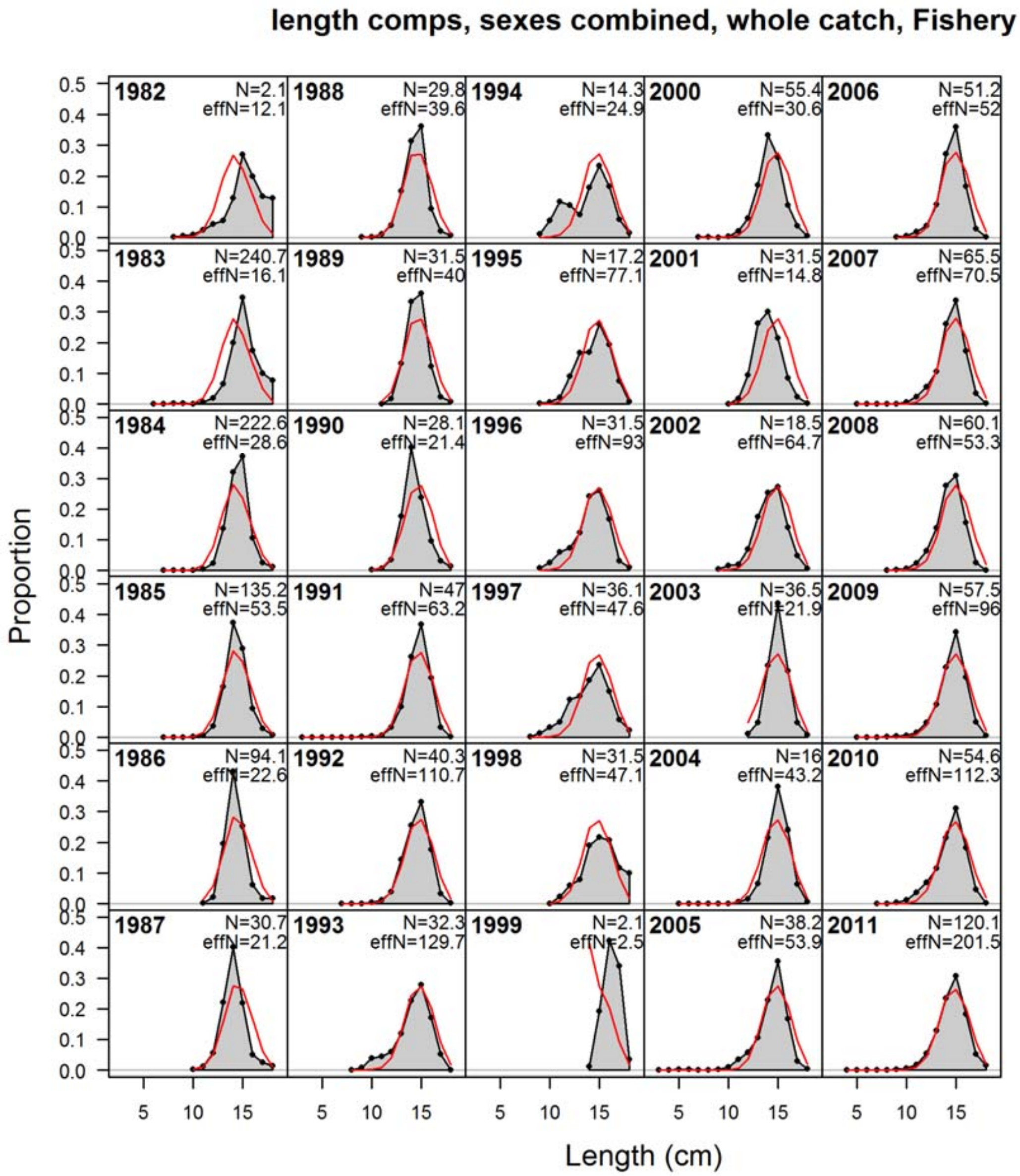


length comp data, sexes combined, whole catch, NperTow+mm
1982
N=88.3
1994
N=123.5
2011
N=86.4
1983
N=92.2
1997
N=121.6
1984
N=6.4
1999
N=119
1986
N=99.8
2002
N=116.5
1989
N=101.1
2005
N=96
1992
N=107.5
2008
N=121
Proportion
Length (cm)

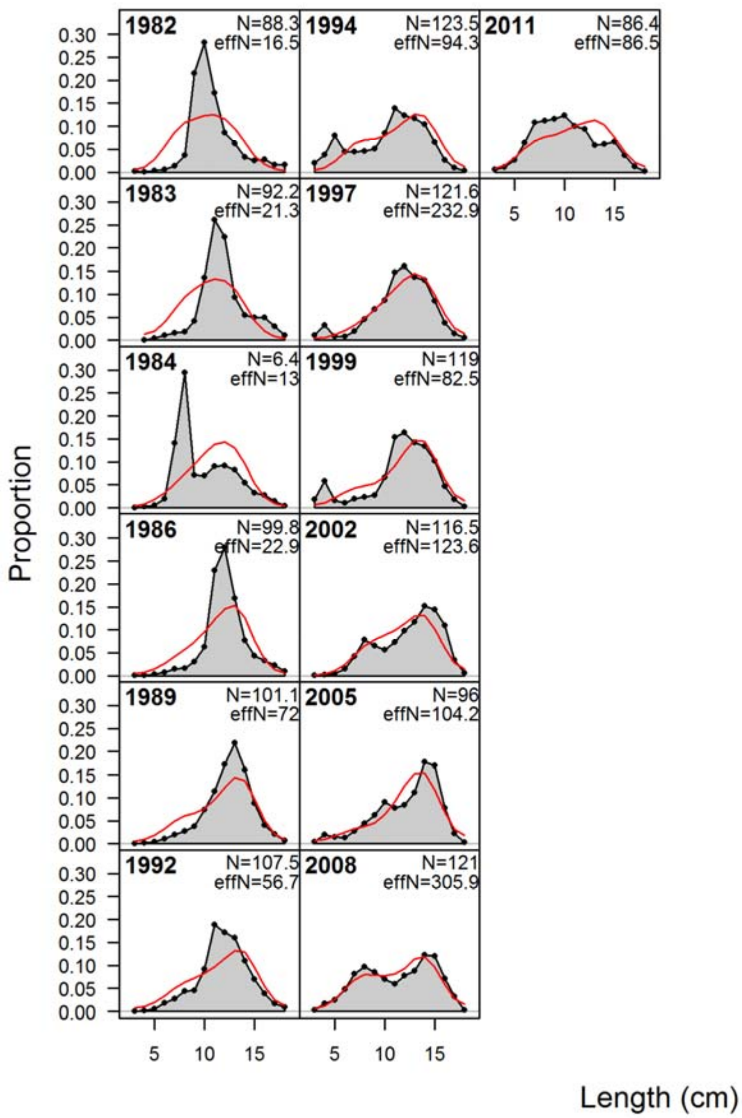

length comp data, sexes combined, whole catch, comparing across f
Fishery
NperTow+mm
Length (cm)
Year
20
15
10
5
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009

engtth comp data, sexes combined, whole catch, aggregated across time b

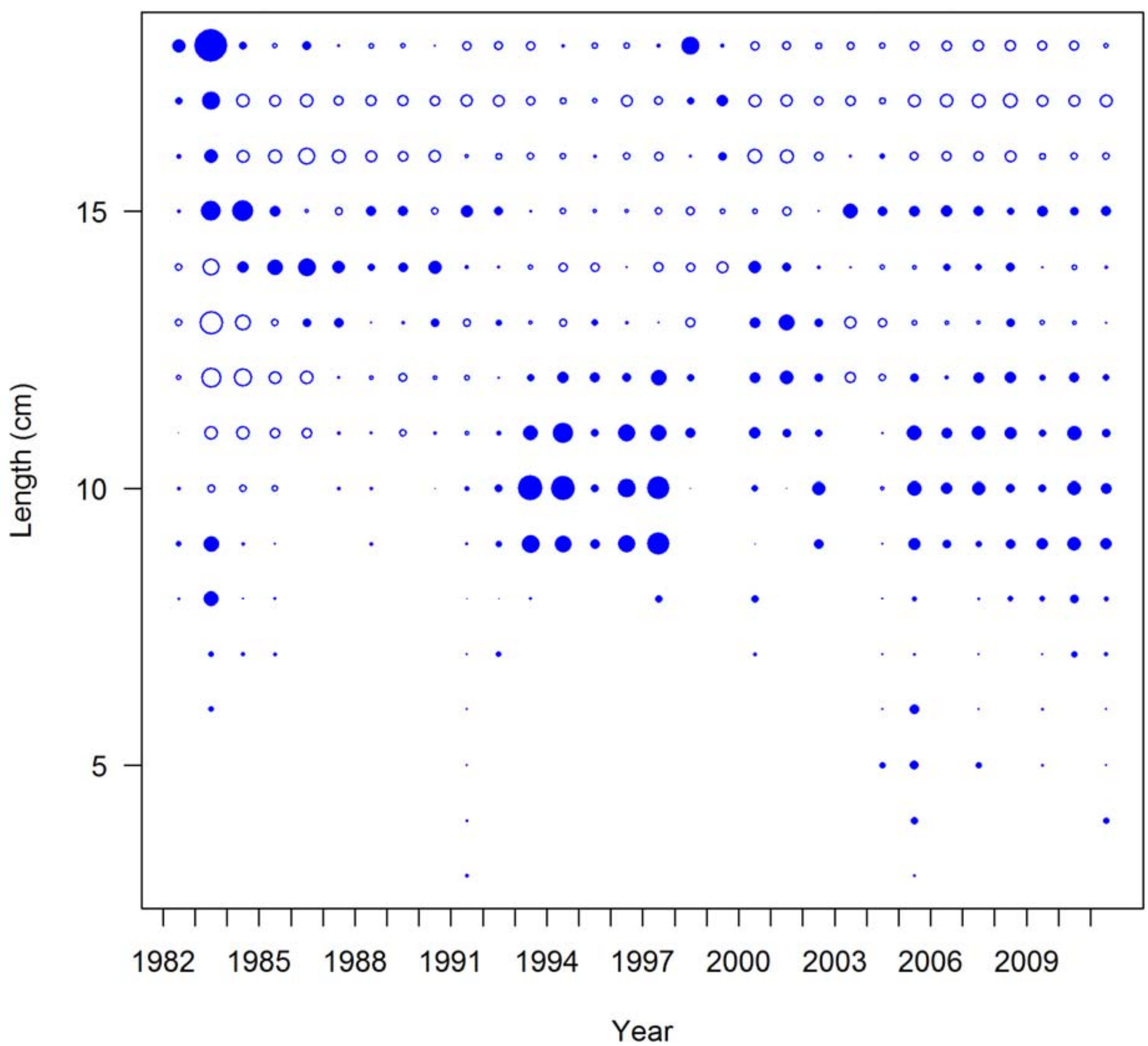


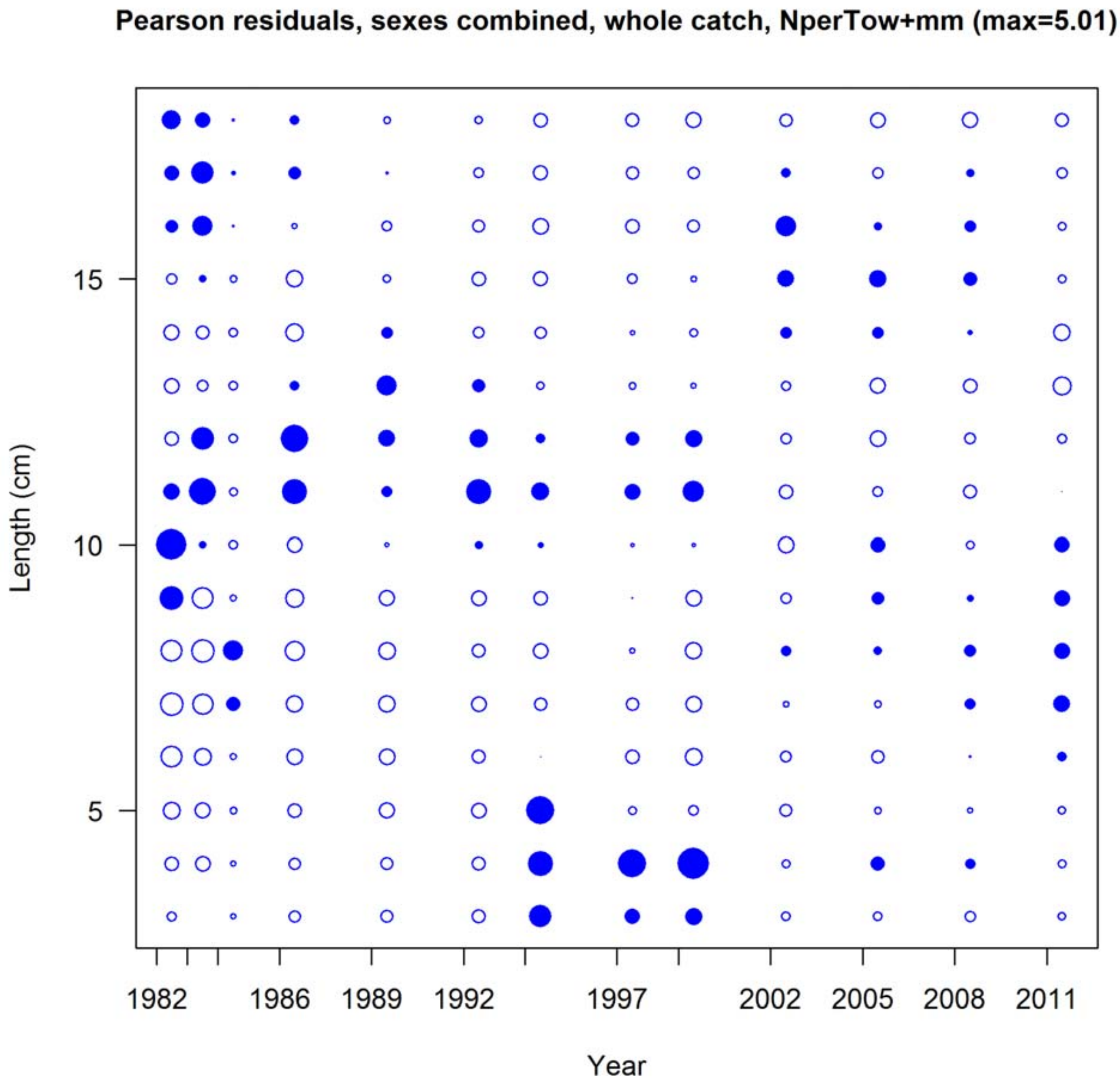

length comps, sexes combined, whole catch, Fishery
1982 N=2.1 effN=12.1
1988 N=29.8 effN=39.6
1994 N=14.3 effN=24.9
2000 N=55.4 effN=30.6
2006 N=51.2 effN=52
1983 N=240.7 effN=16.1
1989 N=31.5 effN=40
1995 N=17.2 effN=77.1
2001 N=31.5 effN=14.8
2007 N=65.5 effN=70.5
1984 N=222.6 effN=28.6
1990 N=28.1 effN=21.4
1996 N=31.5 effN=93
2002 N=18.5 effN=64.7
2008 N=60.1 effN=53.3
1985 N=135.2 effN=53.5
1991 N=47 effN=63.2
1997 N=36.1 effN=47.6
2003 N=36.5 effN=21.9
2009 N=57.5 effN=96
1986 N=94.1 effN=22.6
1992 N=40.3 effN=110.7
1998 N=31.5 effN=47.1
2004 N=16 effN=43.2
2010 N=54.6 effN=112.3
1987 N=30.7 effN=21.2
1993 N=32.3 effN=129.7
1999 N=2.1 effN=2.5
2005 N=38.2 effN=53.9
2011 N=120.1 effN=201.5
Proportion
0.0 0.1 0.2 0.3 0.4 0.5
5 10 15
Length (cm)

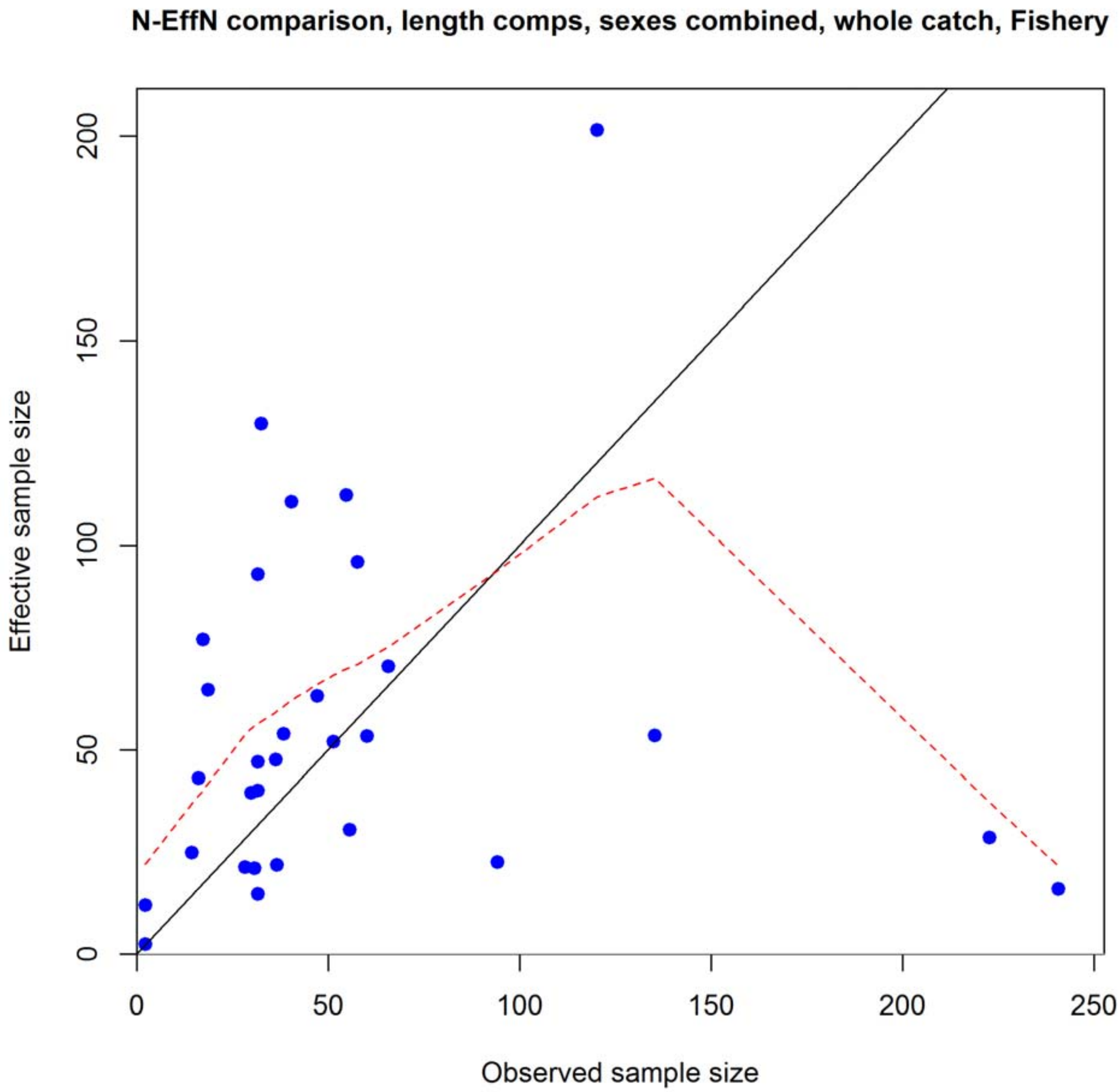
length comps, sexes combined, whole catch, NperTow+mm

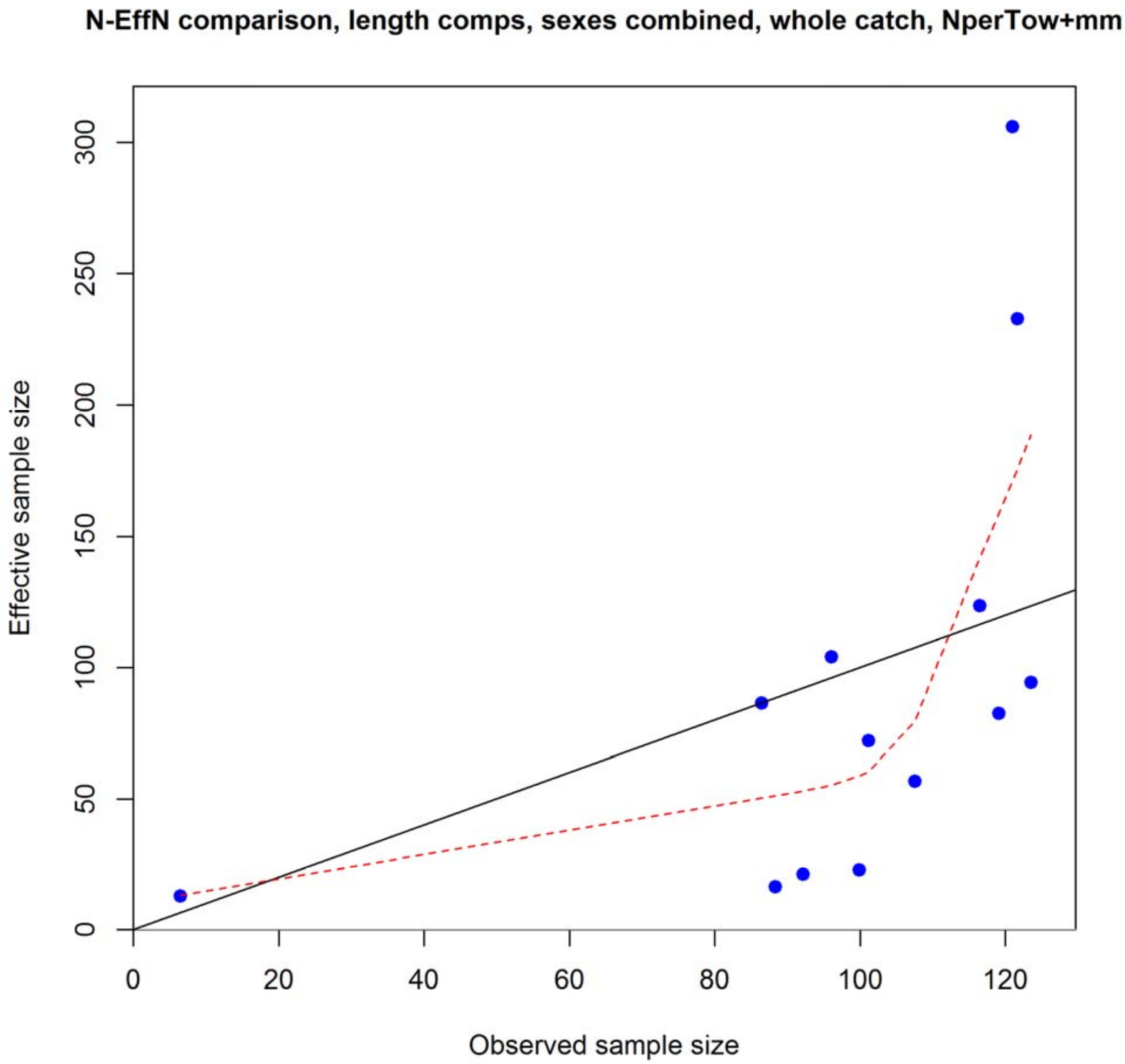


Pearson residuals, sexes combined, whole catch, Fishery (max=11.27)



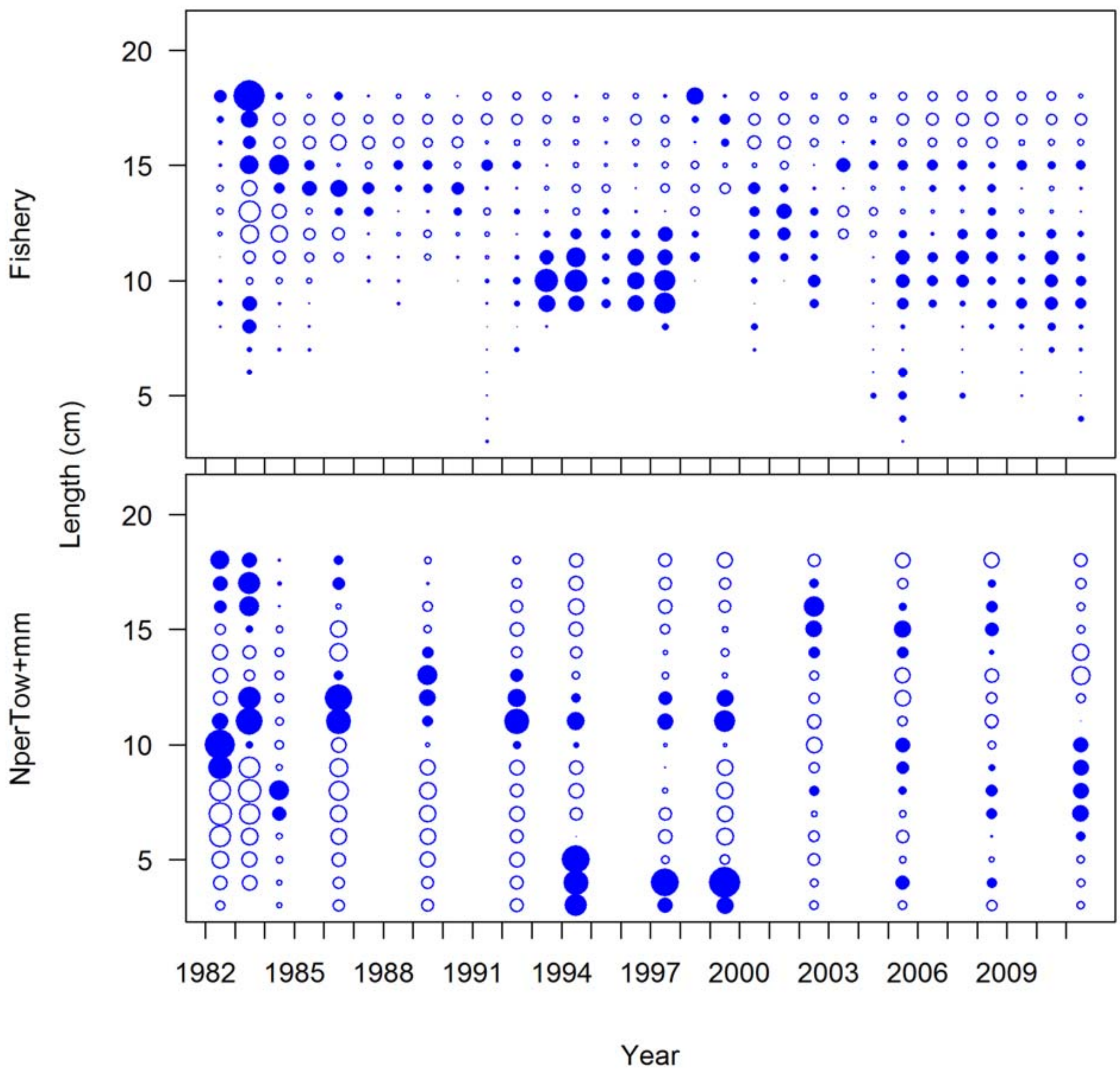

Pearson residuals, sexes combined, whole catch, NperTow+mm (max=5.01)
Length (cm)
5
10
15
1982
1986
1989
1992
1997
2002
2005
2008
2011
Year


N-EffN comparison, length comps, sexes combined, whole catch, Fishery
Effective sample size
Observed sample size
0
50
100
150
200
250

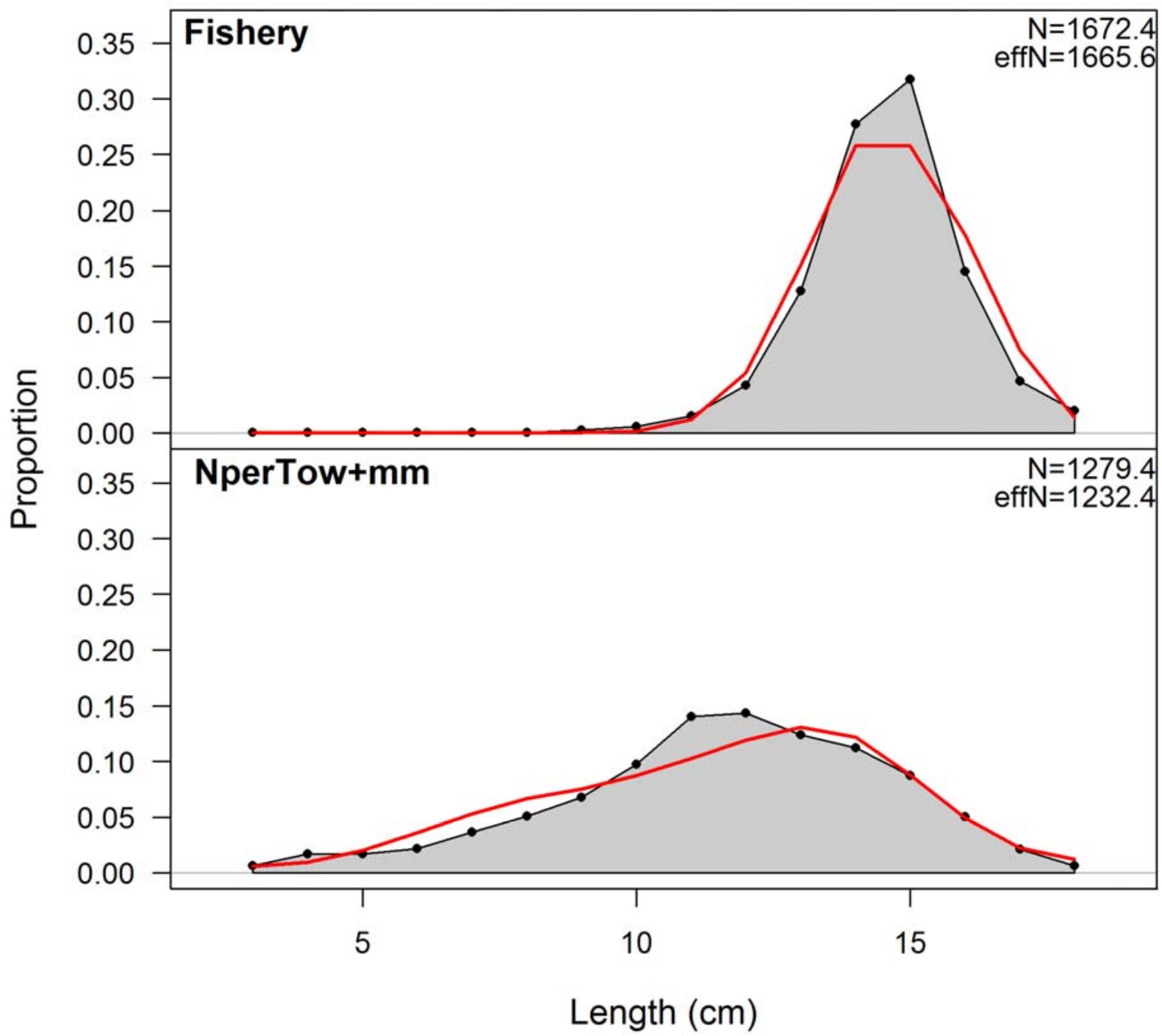


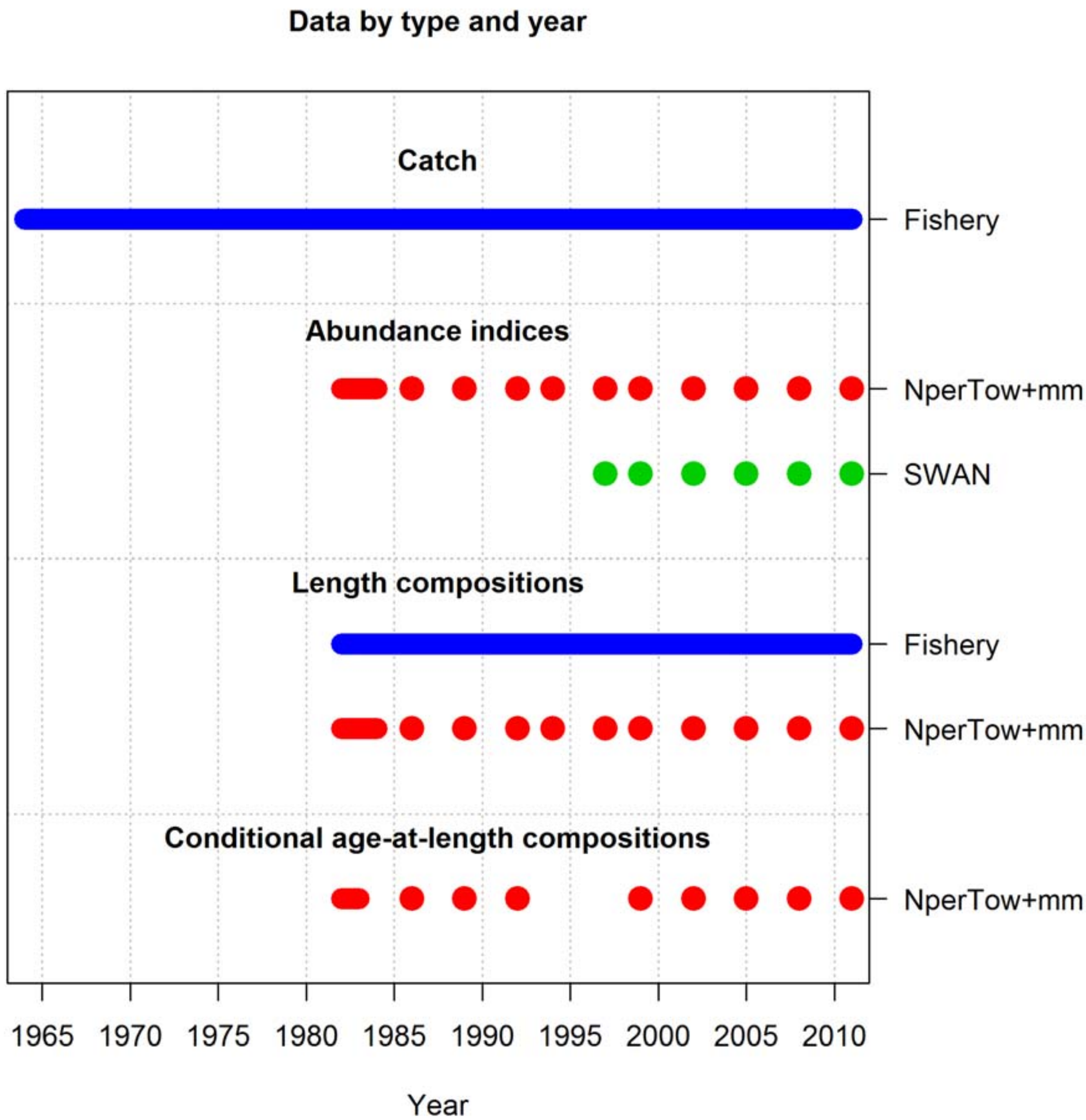
N-EffN comparison, length comps, sexes combined, whole catch, NperTow+mm
Effective sample size
Observed sample size
0
50
100
150
200
250
300
0
20
40
60
80
100
120

Pearson residuals, sexes combined, whole catch, comparing across

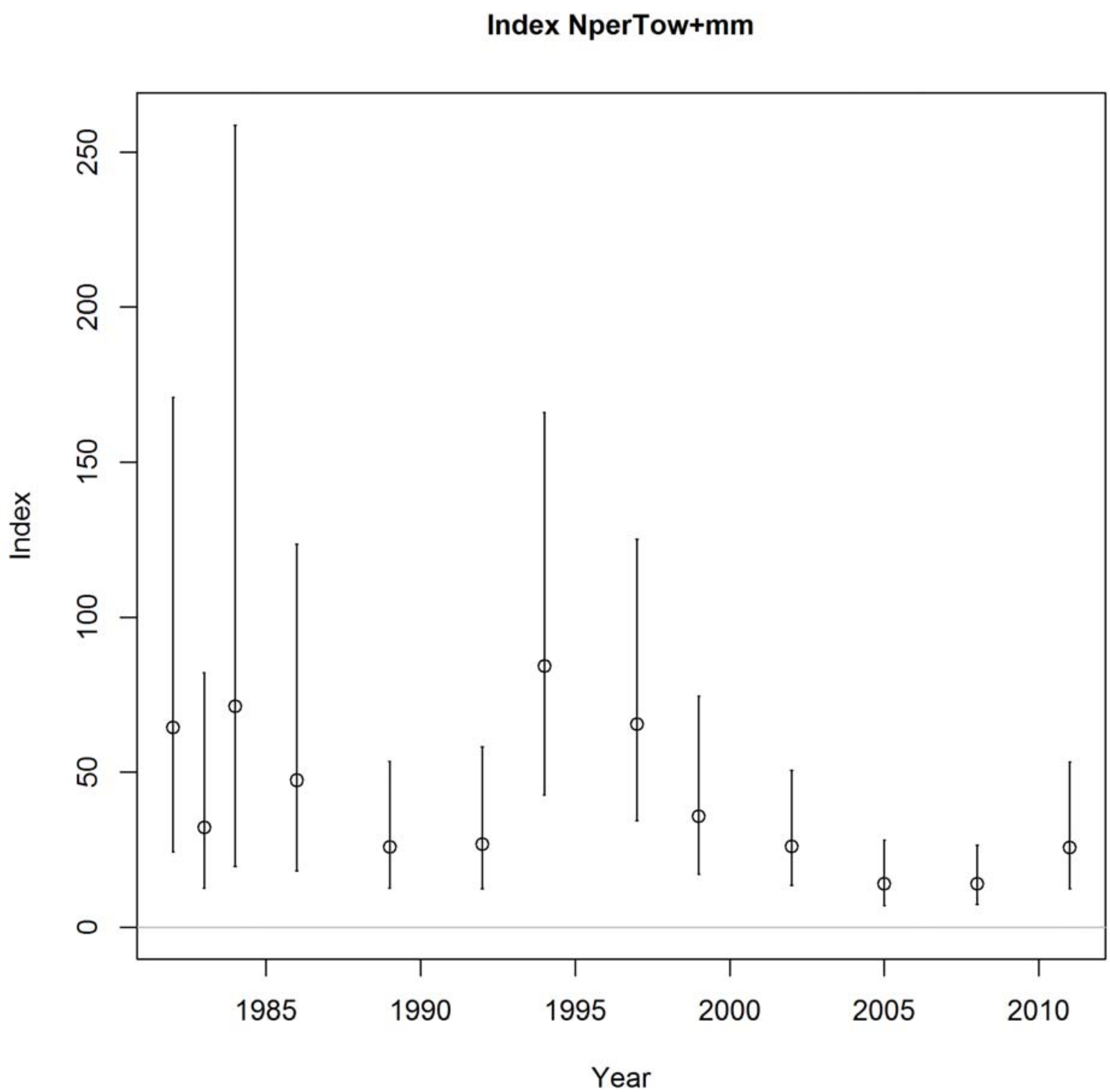


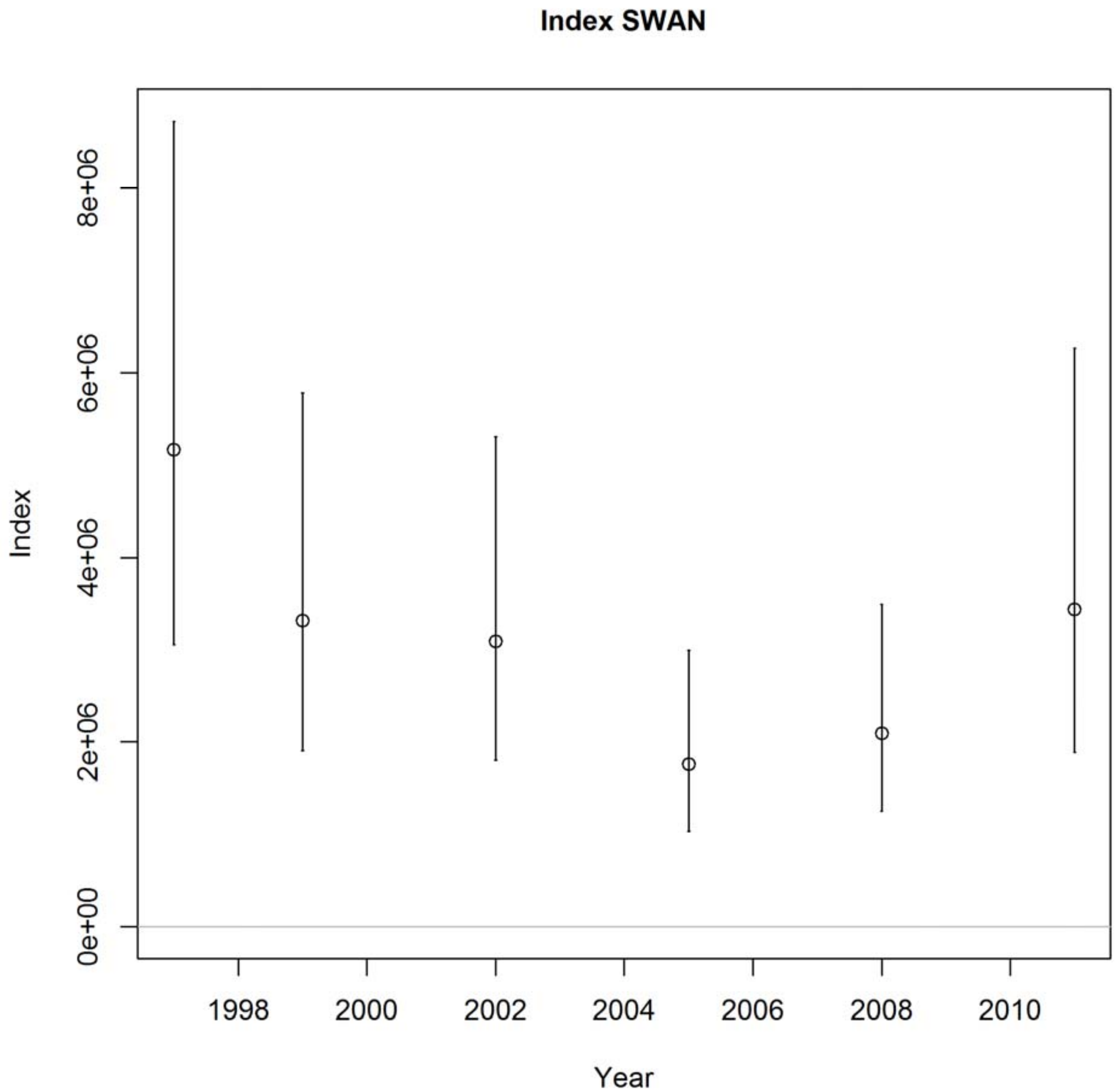
length comps, sexes combined, whole catch, aggregated across time by

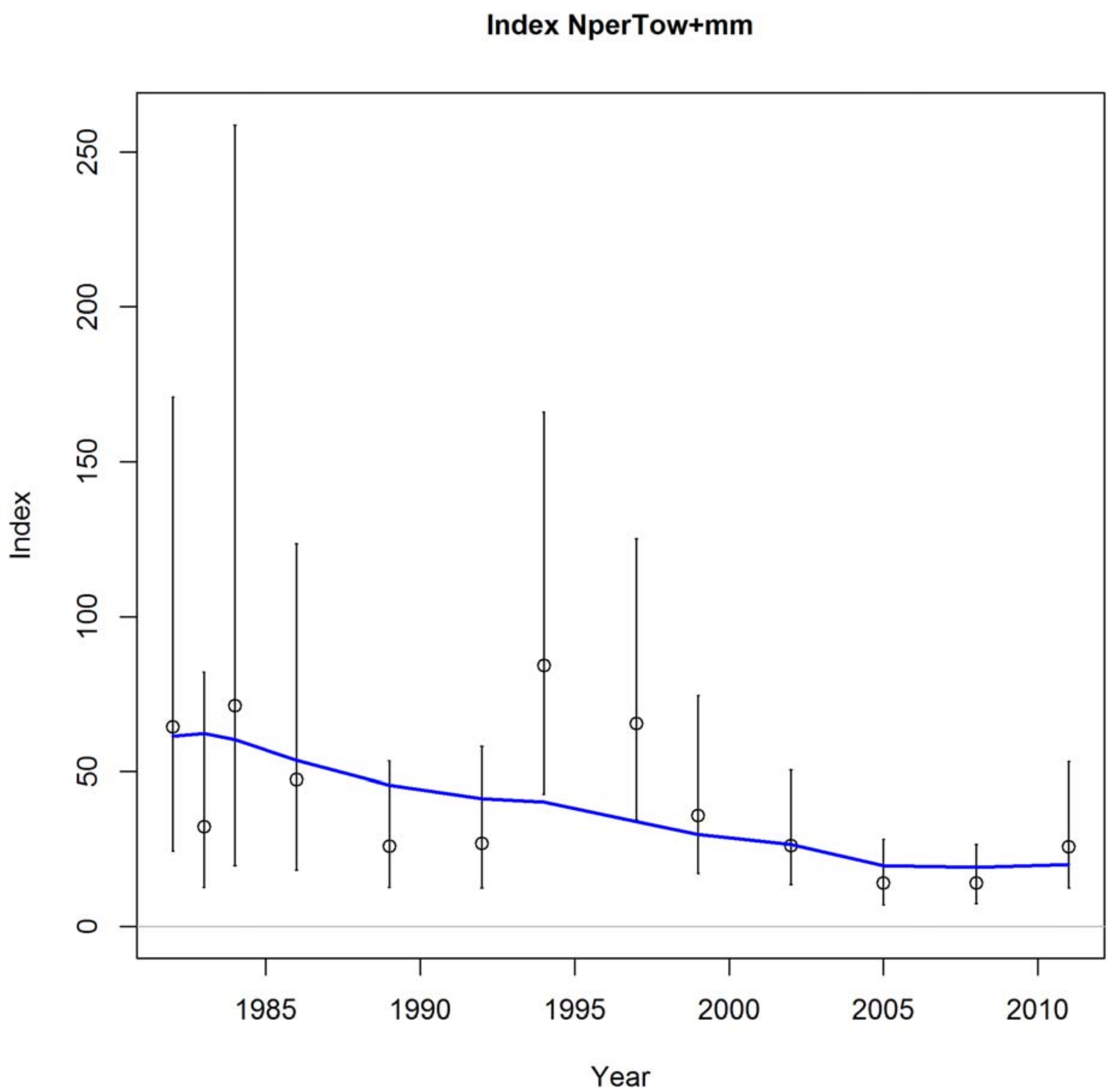


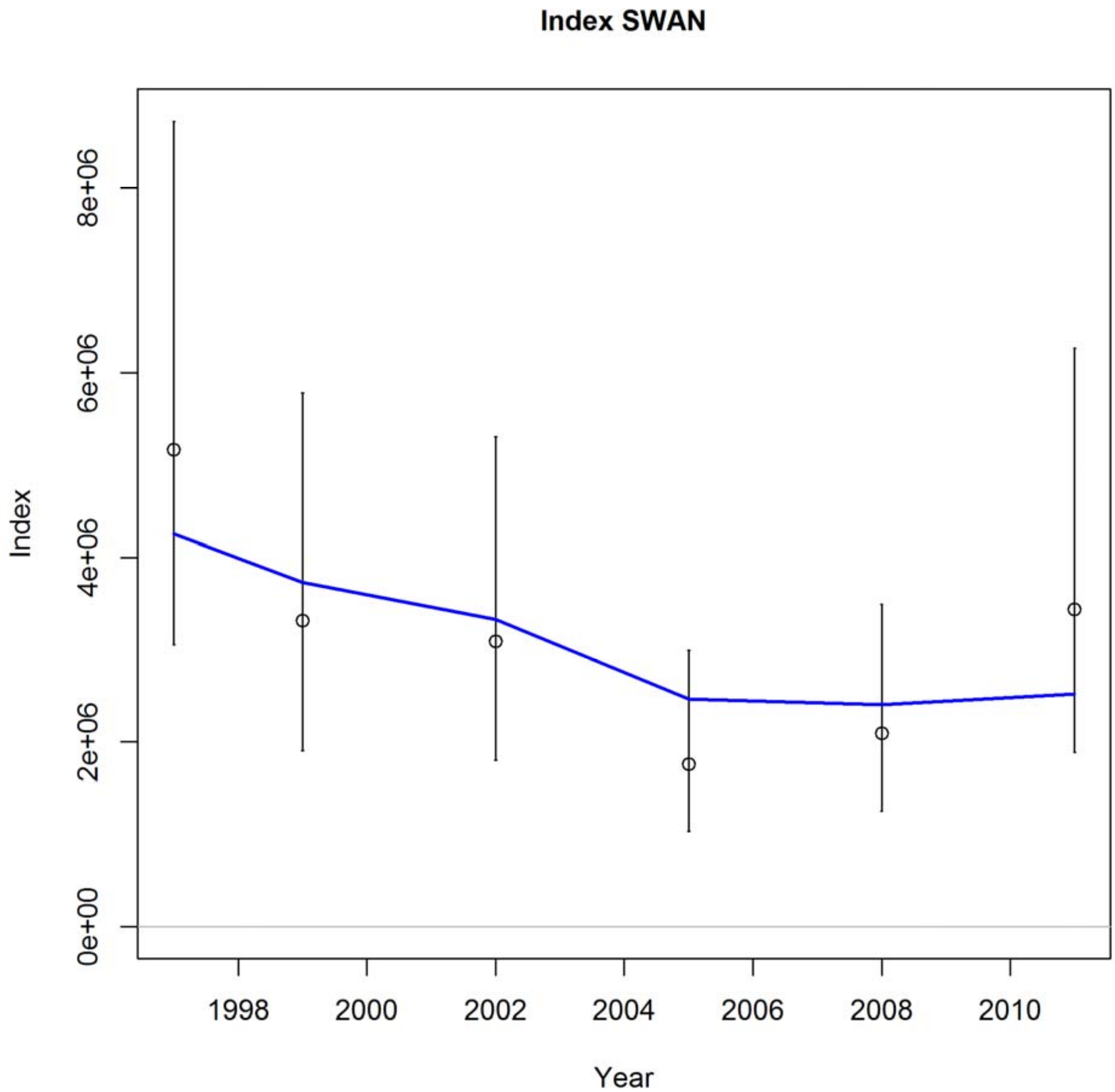


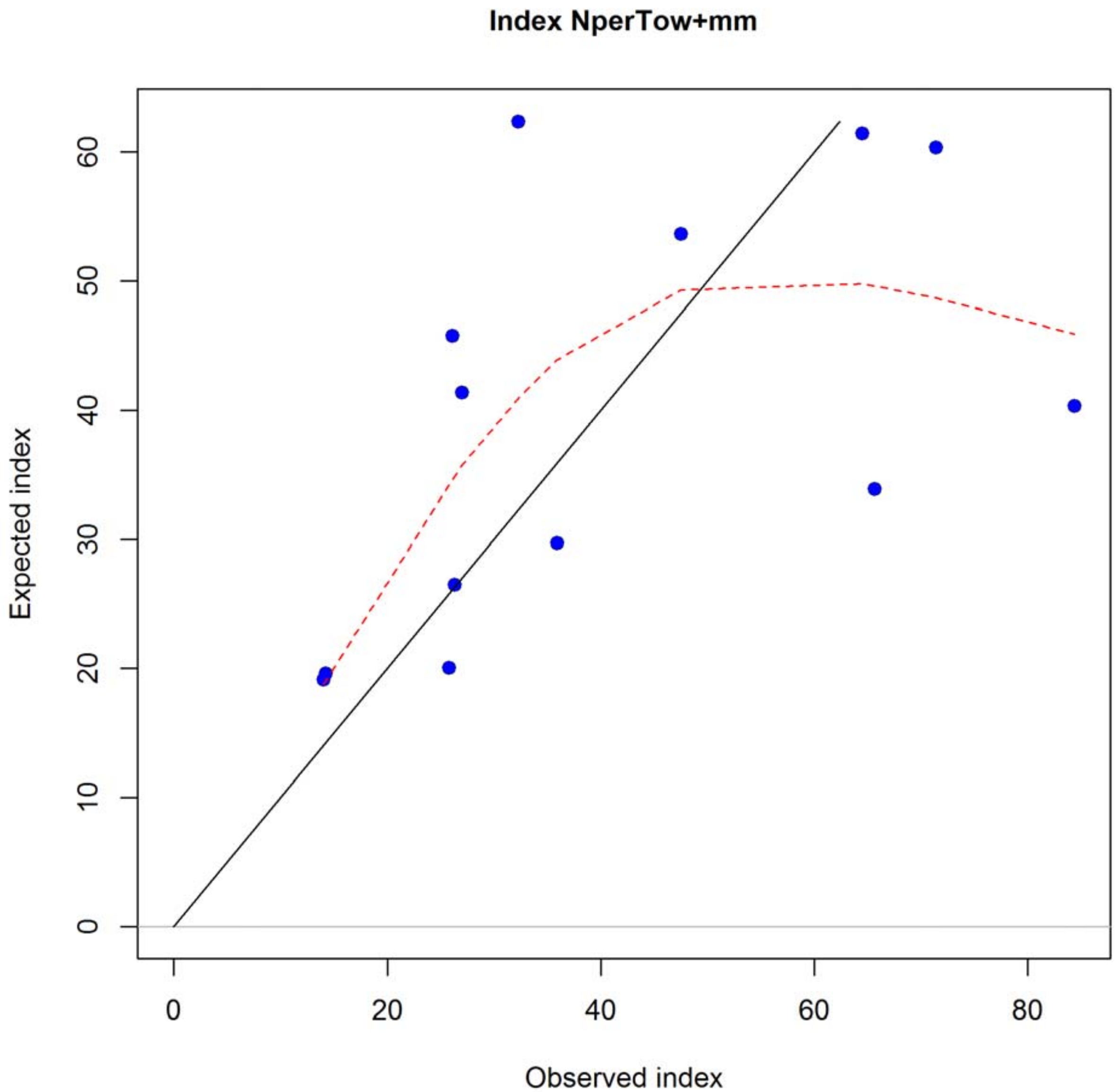
Data by type and year
Catch
Fishery
Abundance indices
NperTow+mm
SWAN
Length compositions
Fishery
NperTow+mm
Conditional age-at-length compositions
NperTow+mm
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

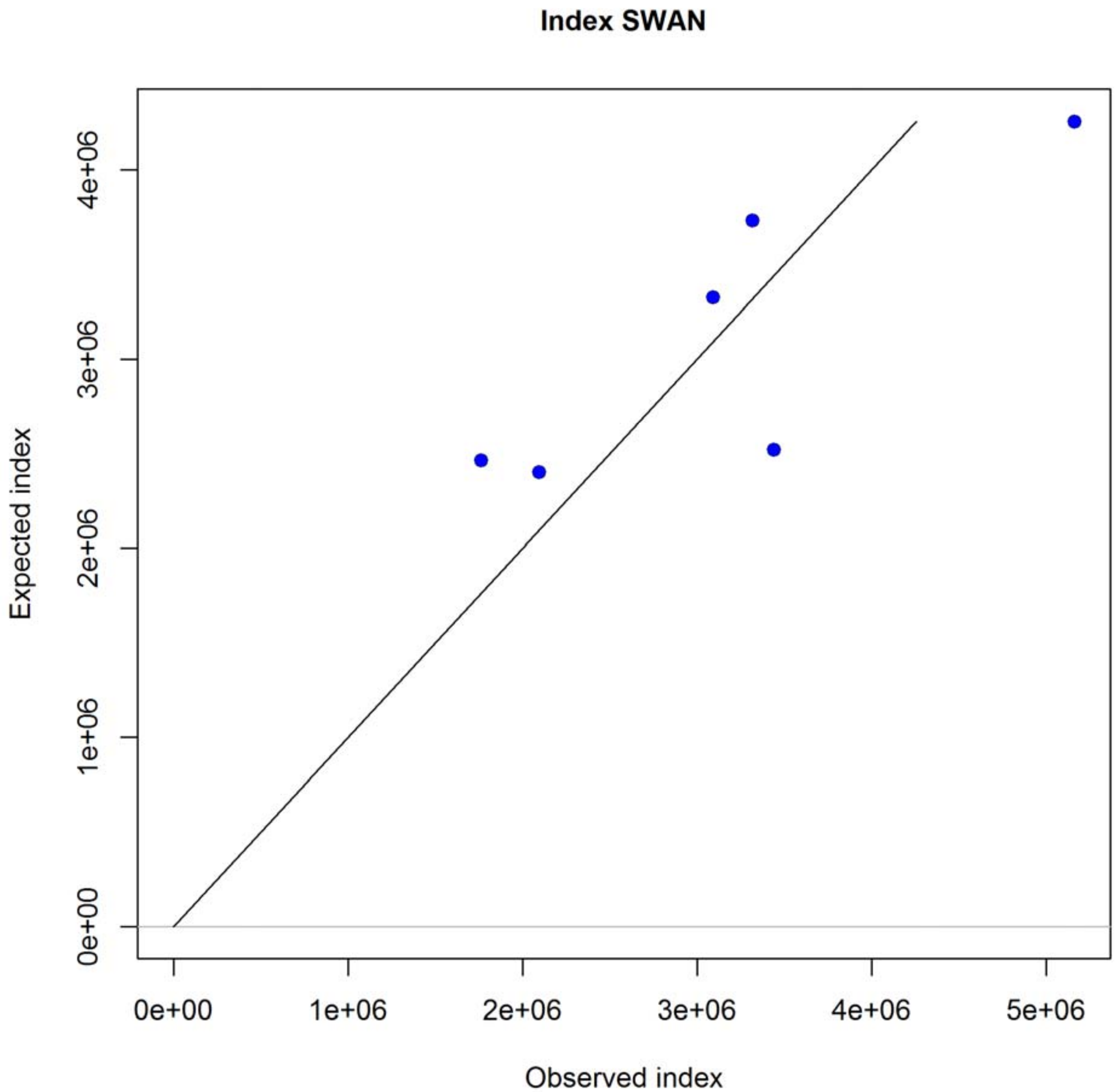

Index NperTow+mm
Index
0
50
100
150
200
250
1985
1990
1995
2000
2005
2010
Year

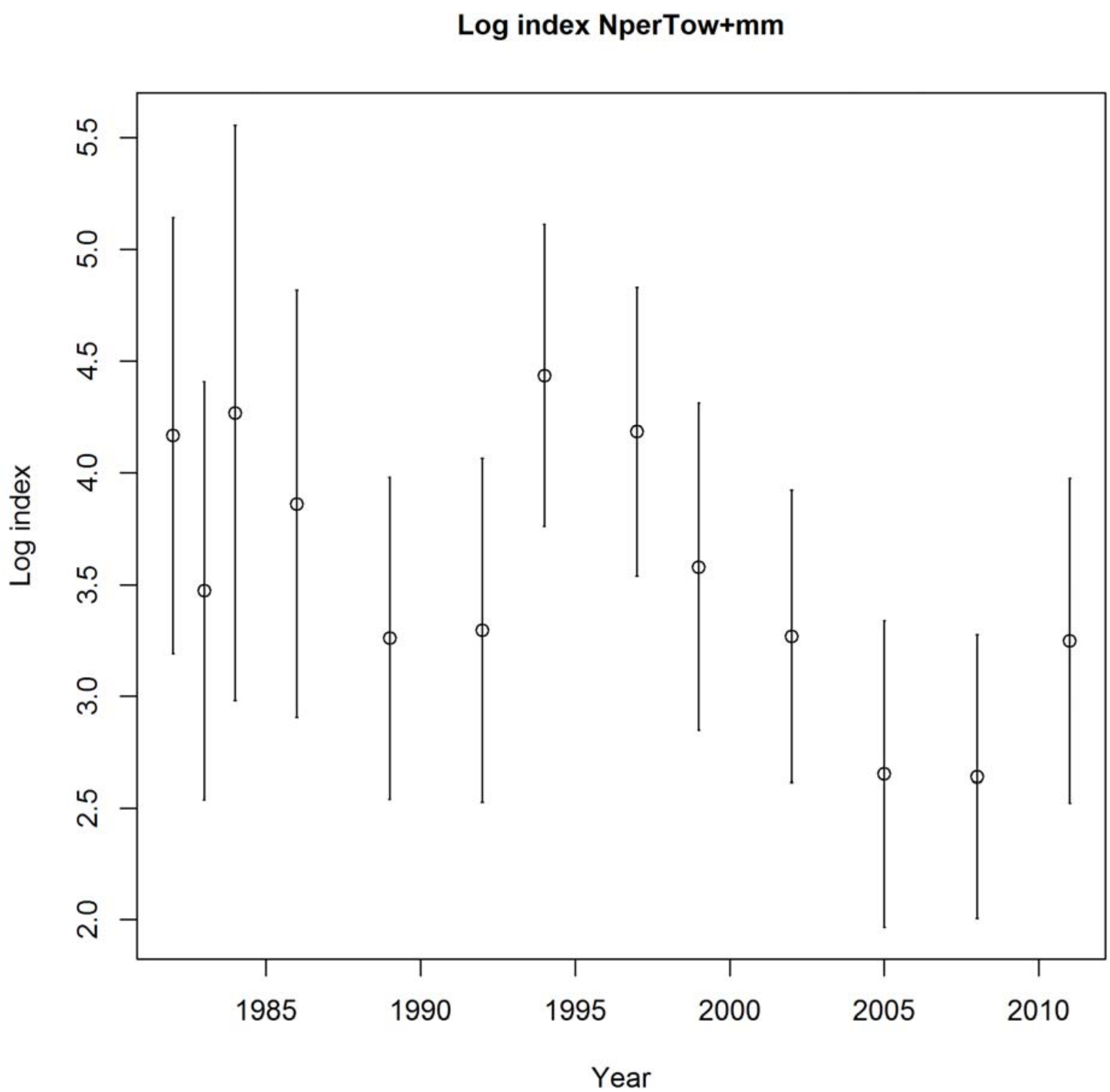

Index SWAN
Index
8e+06
6e+06
4e+06
2e+06
0e+00
1998
2000
2002
2004
2006
2008
2010
Year

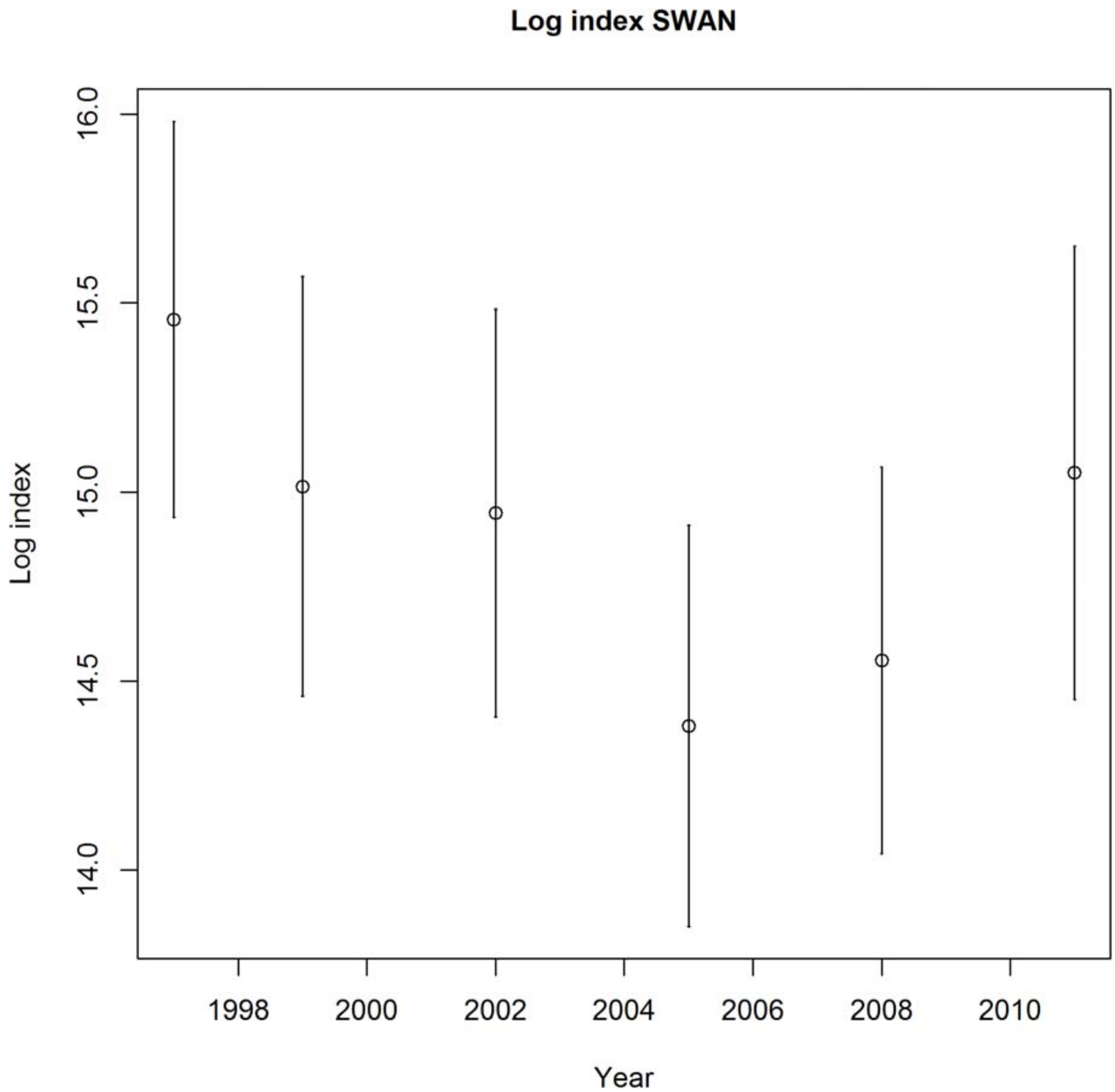

Index NperTow+mm
Index
0
50
100
150
200
250
1985
1990
1995
2000
2005
2010
Year

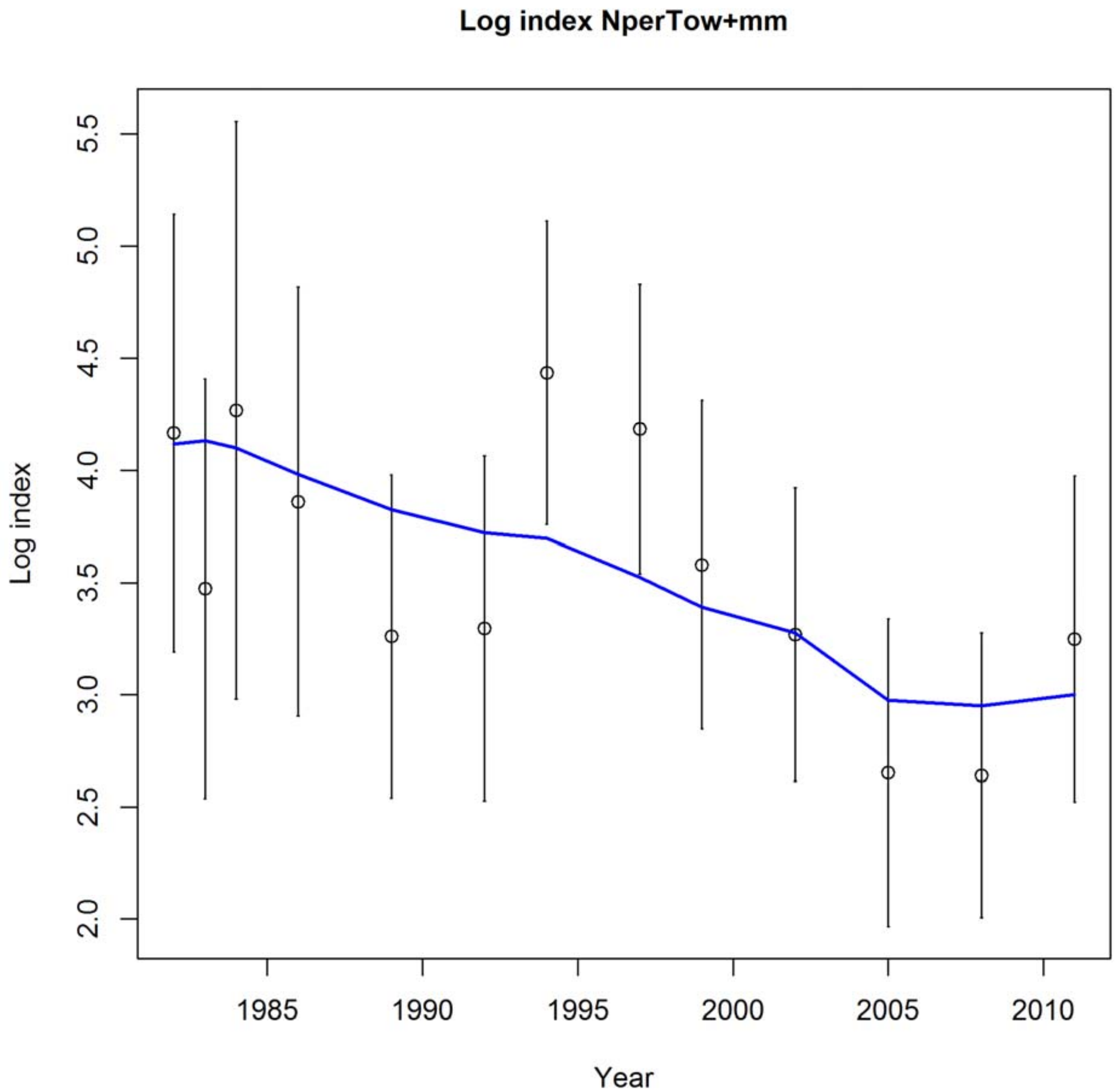

Index SWAN
8e+06
6e+06
4e+06
2e+06
0e+00
Index
1998
2000
2002
2004
2006
2008
2010
Year


Index NperTow+mm
Expected index
Observed index
0
10
20
30
40
50
60
0
20
40
60
80

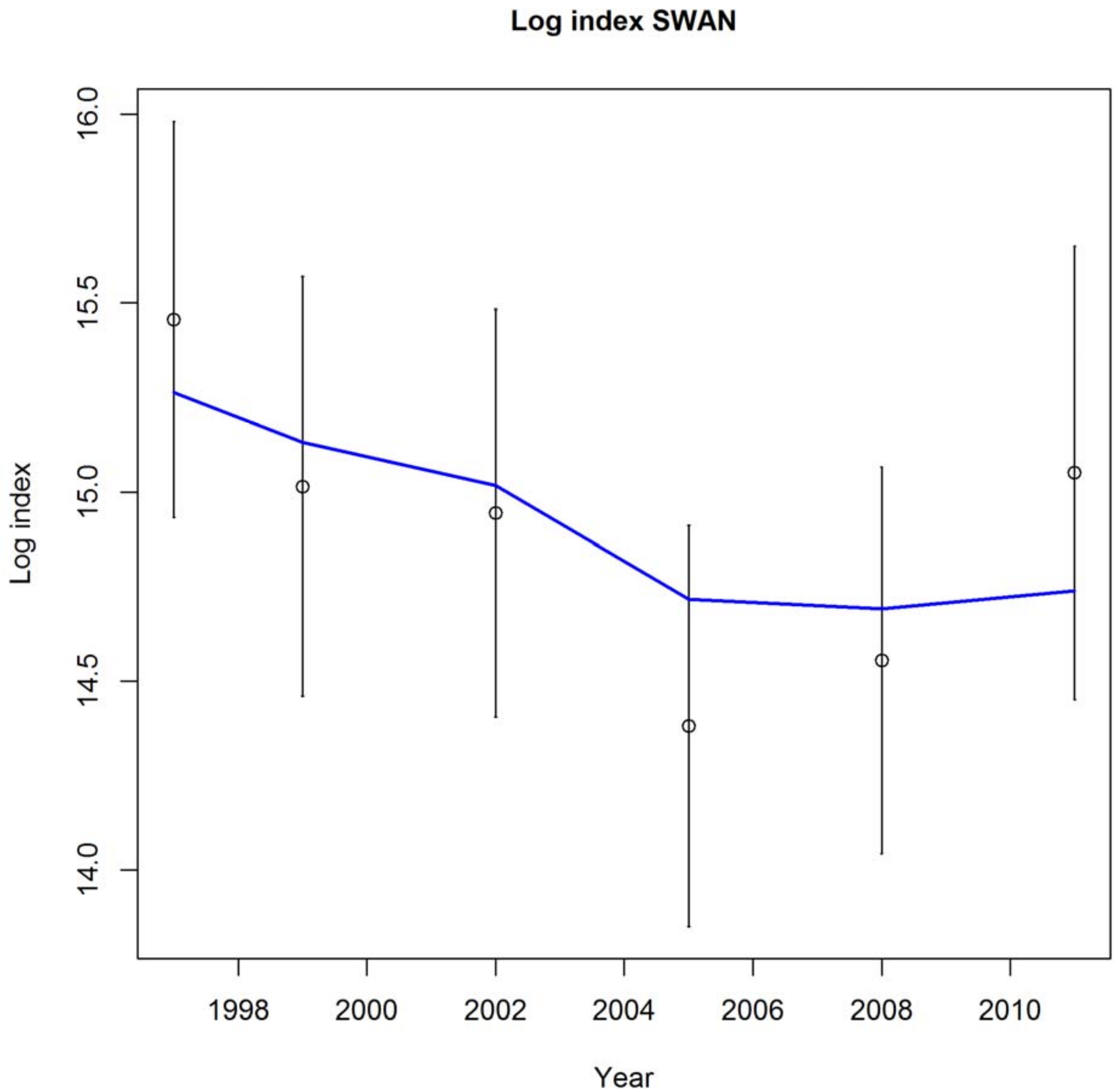

Index SWAN
Expected index
Observed index
0e+00
1e+06
2e+06
3e+06
4e+06
5e+06


Log index NperTow+mm
Log index
Year
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
1985
1990
1995
2000
2005
2010

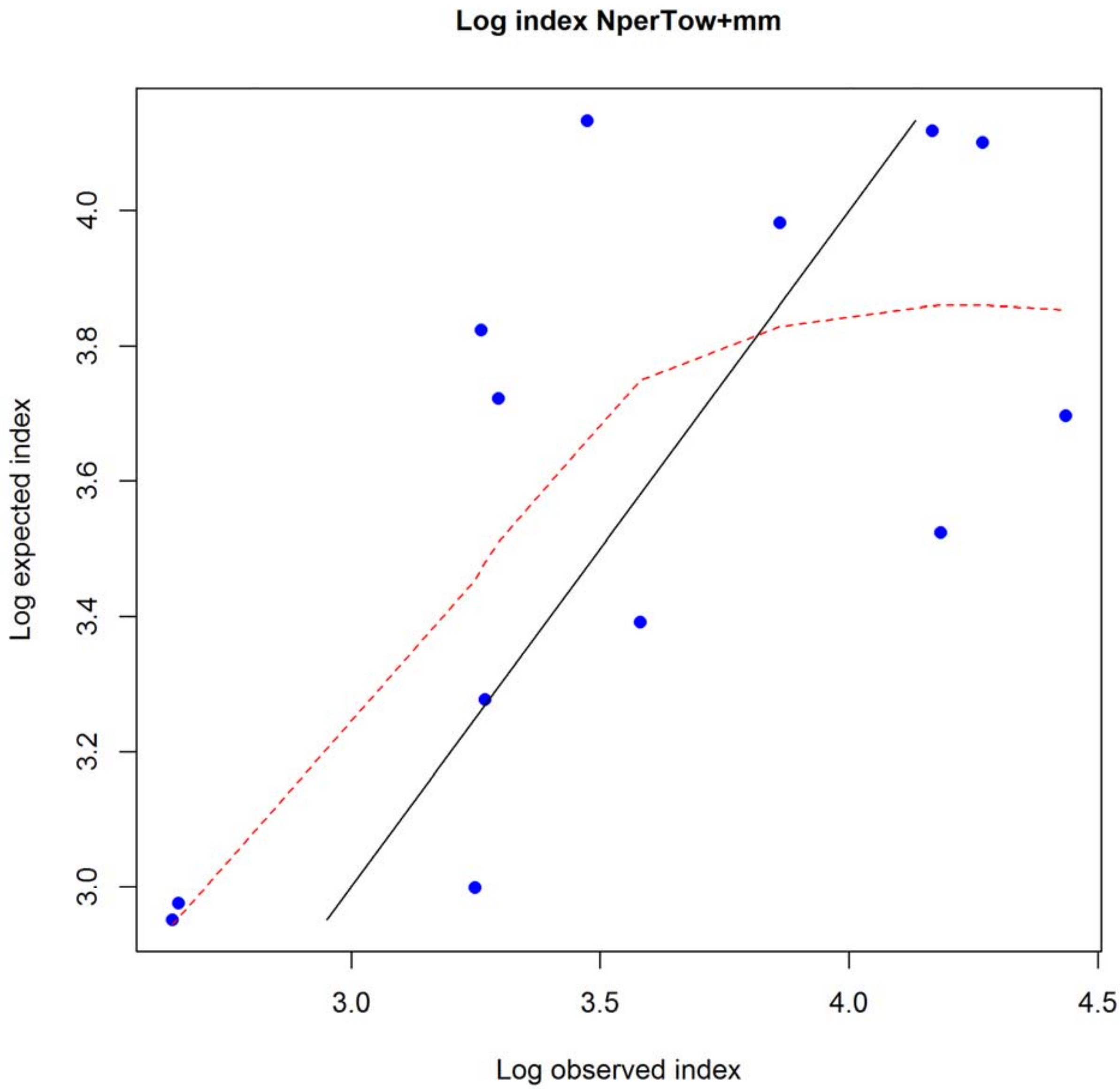

Log index SWAN
Log index
16.0
15.5
15.0
14.5
14.0
1998
2000
2002
2004
2006
2008
2010
Year



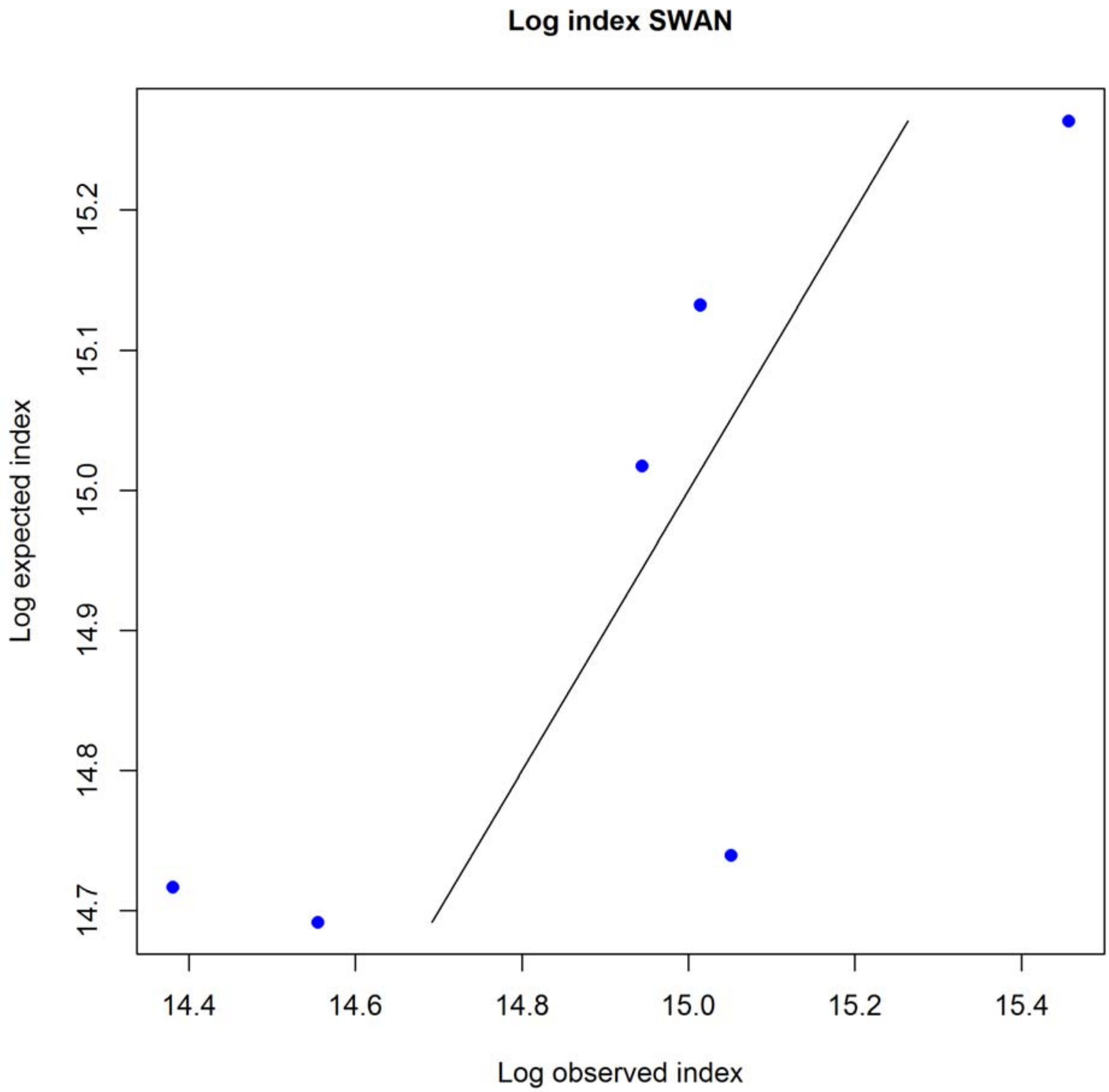
Log index NperTow+mm
Log index
Year
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1985
1990
1995
2000
2005
2010



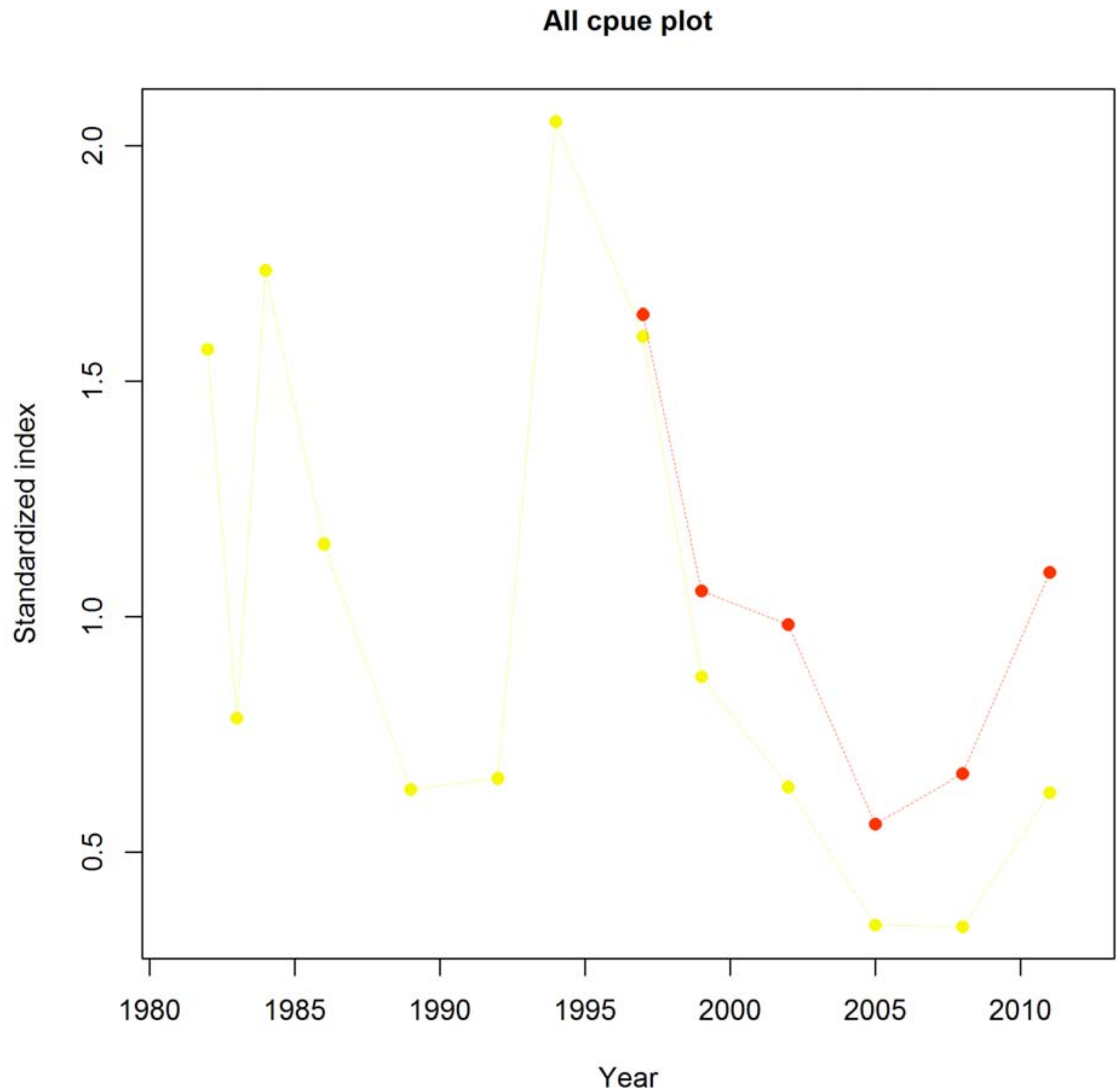
Log index SWAN
Log index
16.0
15.5
15.0
14.5
14.0
1998
2000
2002
2004
2006
2008
2010
Year



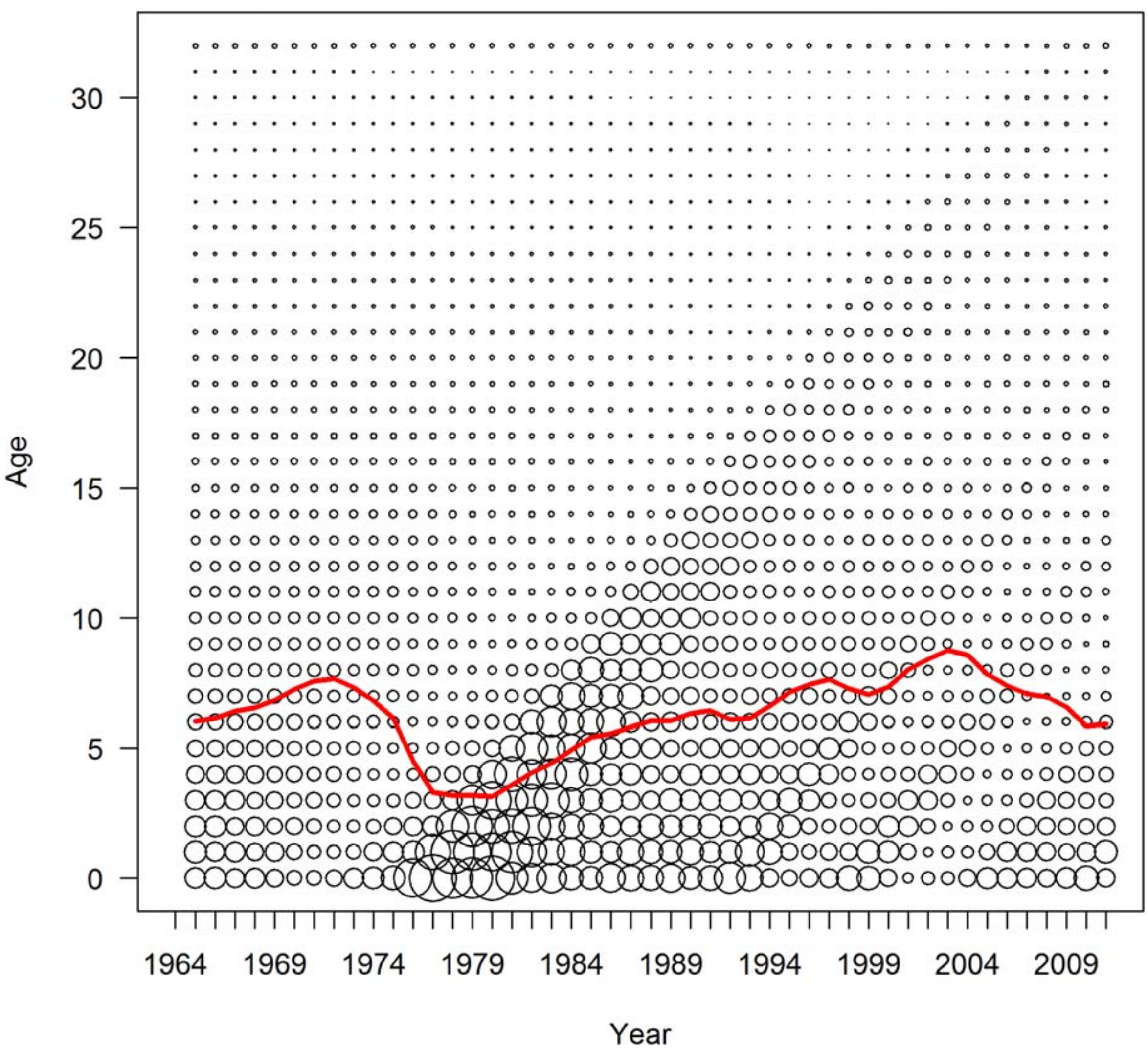
Log index NperTow+mm
Log expected index
Log observed index
3.0
3.2
3.4
3.6
3.8
4.0
3.0
3.5
4.0
4.5

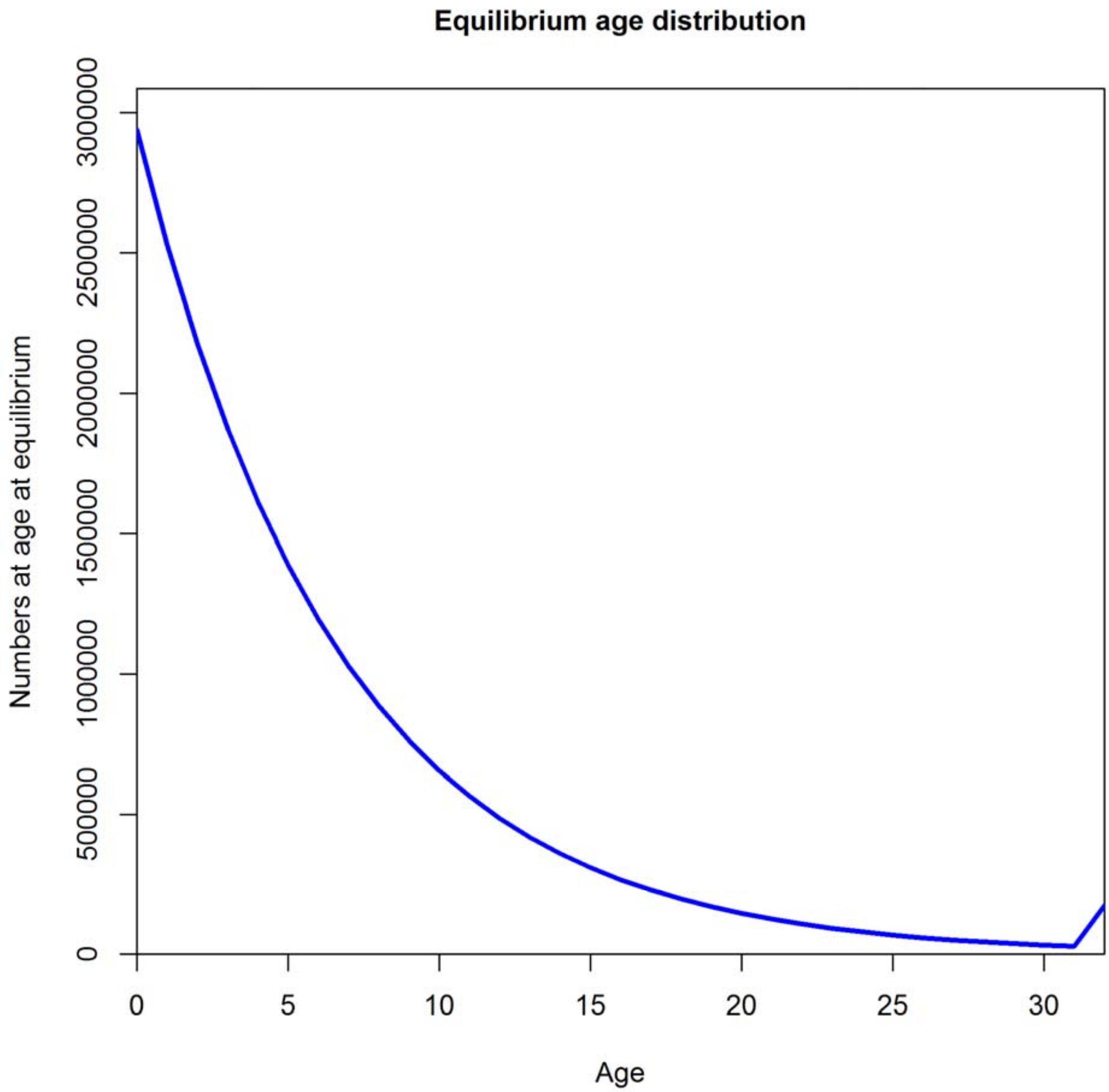


Log index SWAN
Log expected index
Log observed index
14.7
14.8
14.9
15.0
15.1
15.2
14.4
14.6
14.8
15.0
15.2
15.4

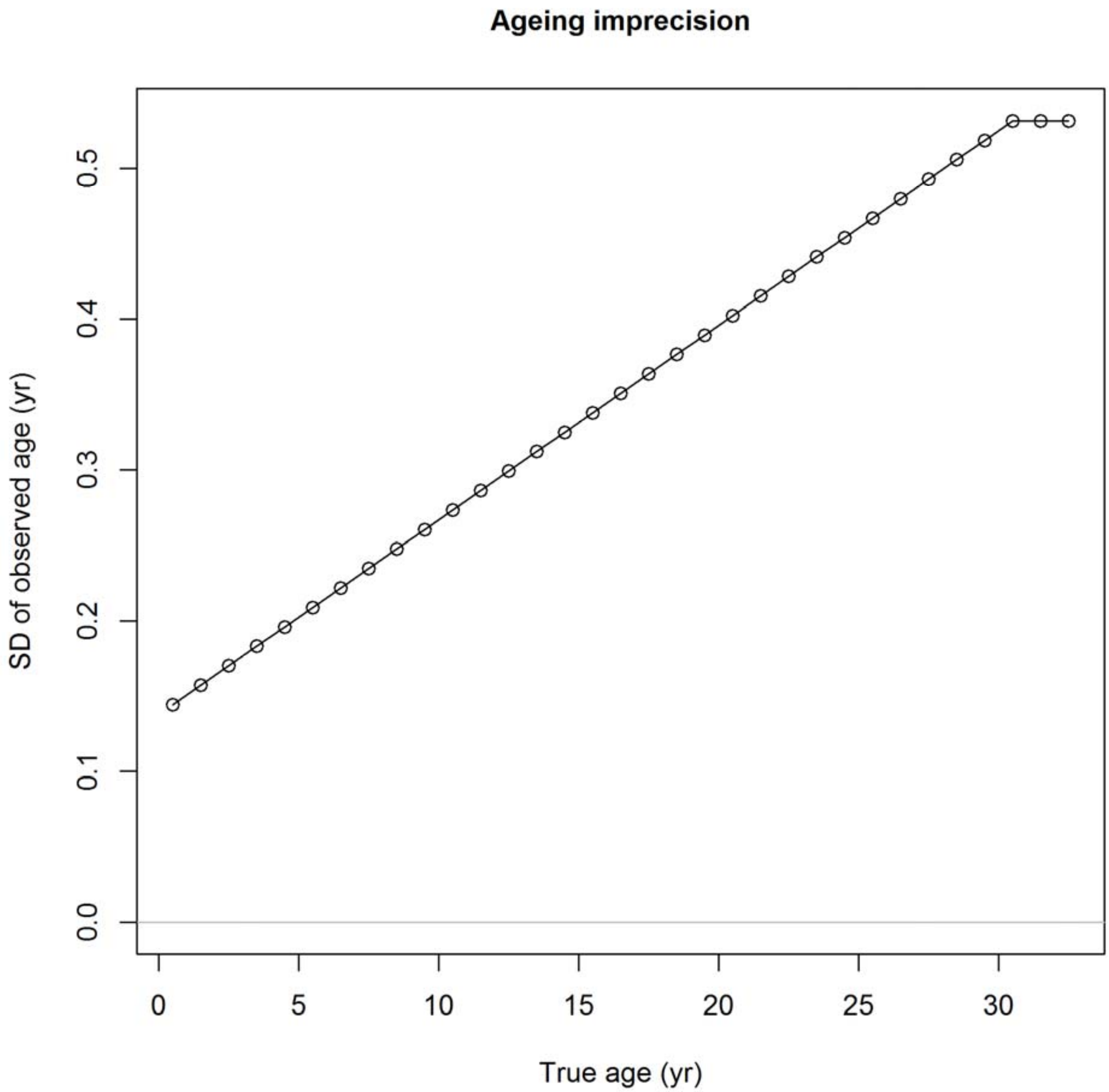

All cpue plot
Standardized index
0.5
1.0
1.5
2.0
1980
1985
1990
1995
2000
2005
2010
Year

Middle of year expected numbers at age in thousands (max=9887690)

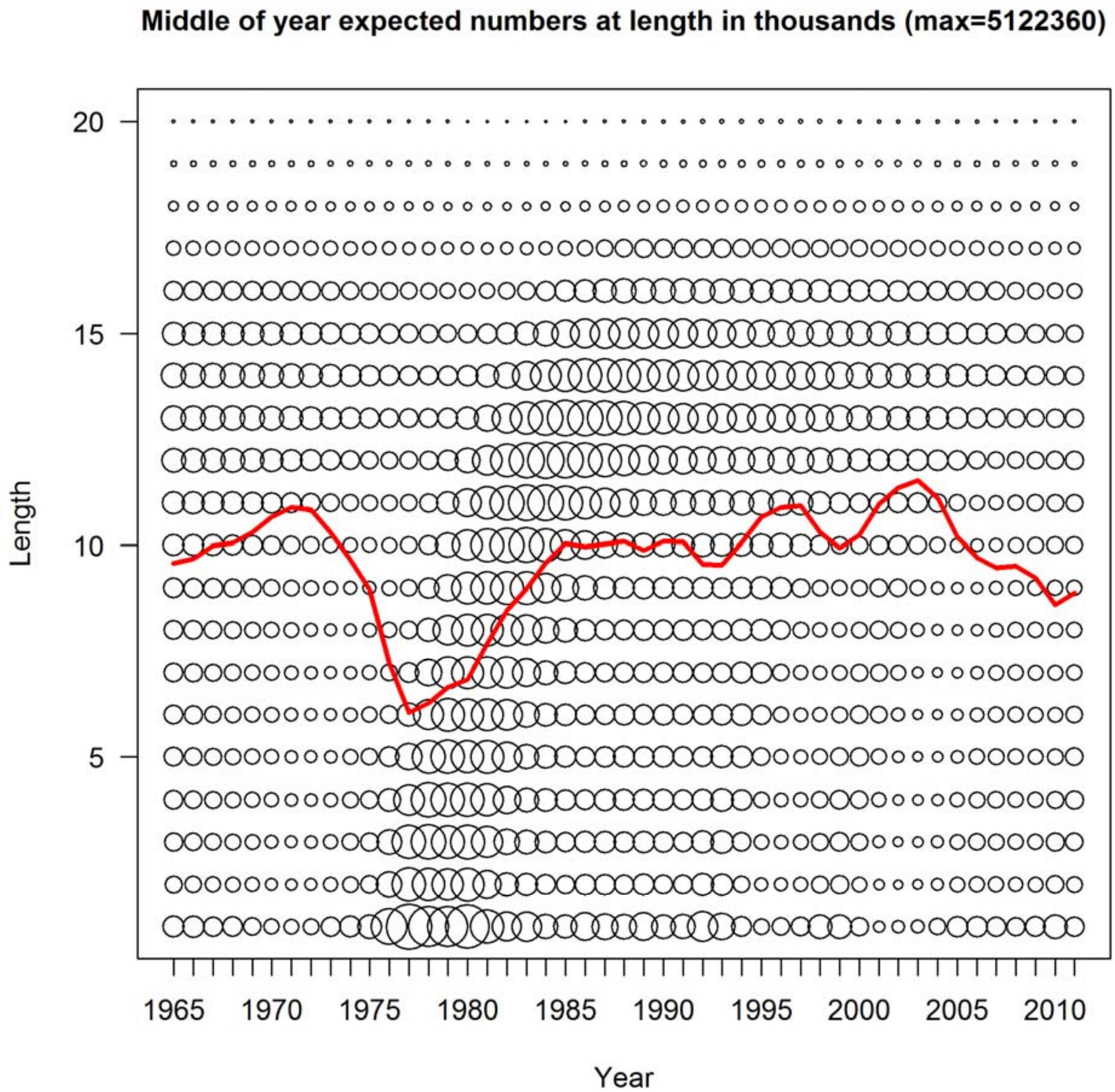




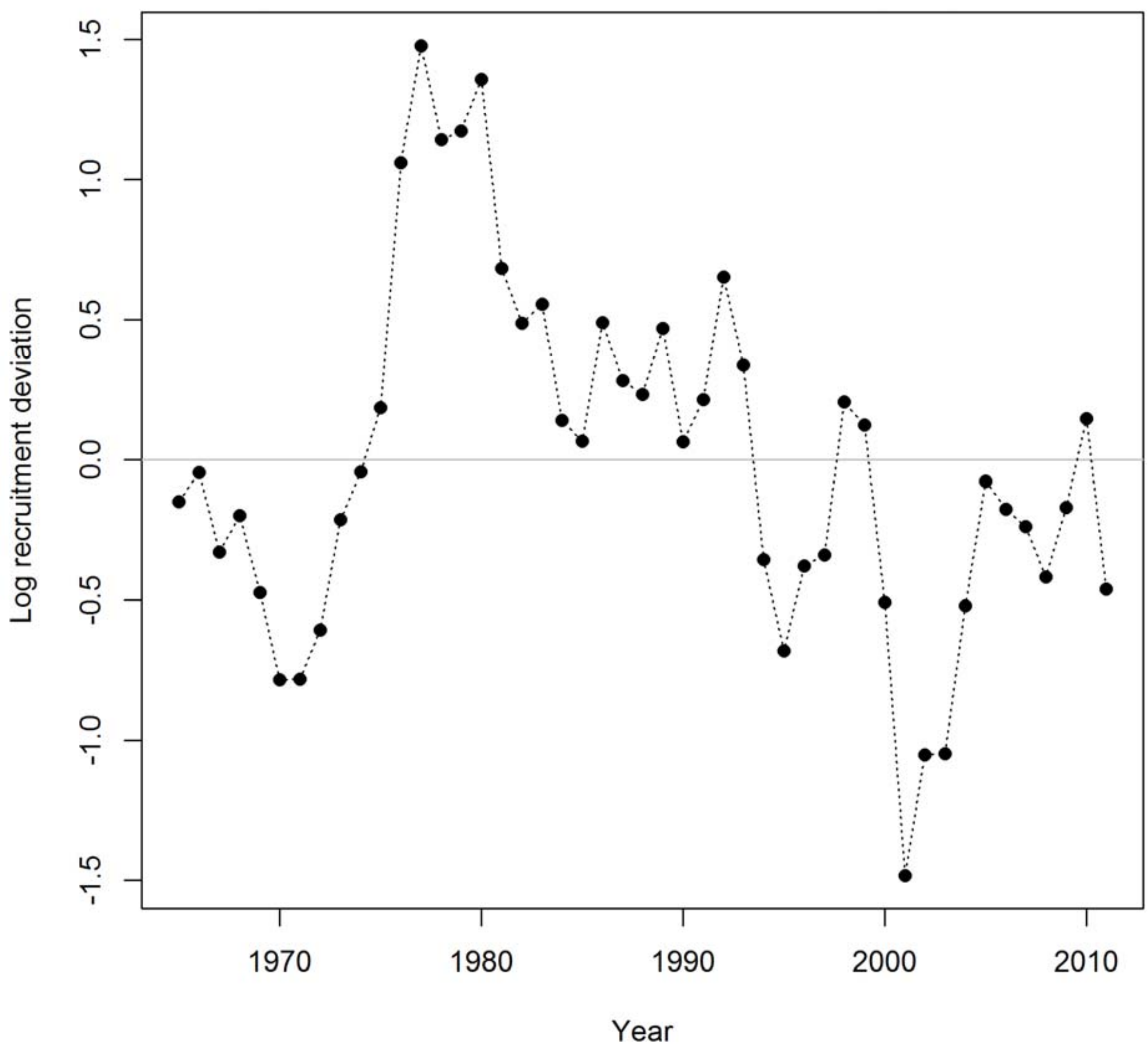
Equilibrium age distribution
Numbers at age at equilibrium
0
500000
1000000
1500000
2000000
2500000
3000000
0
5
10
15
20
25
30
Age



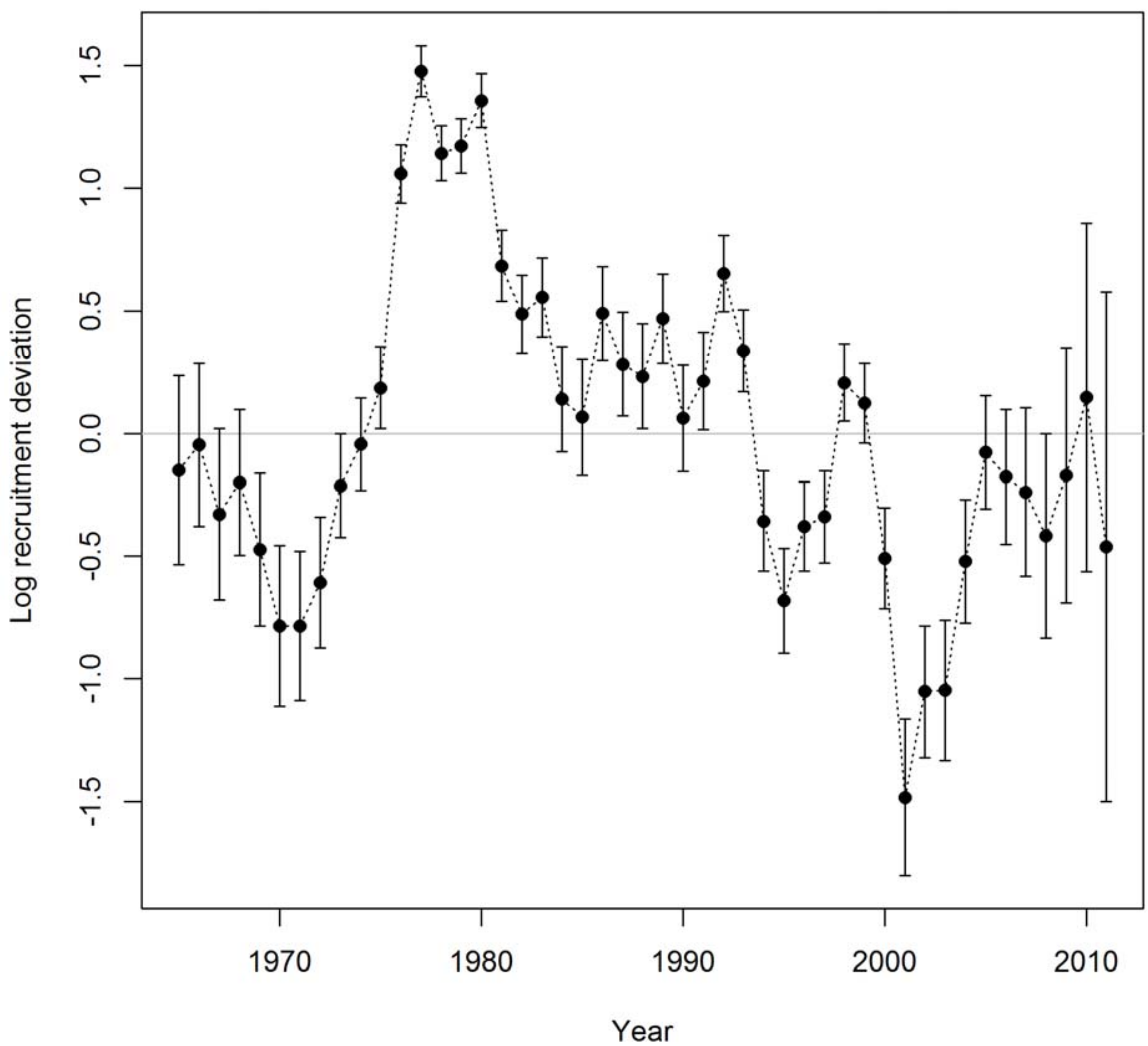
Ageing imprecision
SD of observed age (yr)
0.0
0.1
0.2
0.3
0.4
0.5
0
5
10
15
20
25
30
True age (yr)

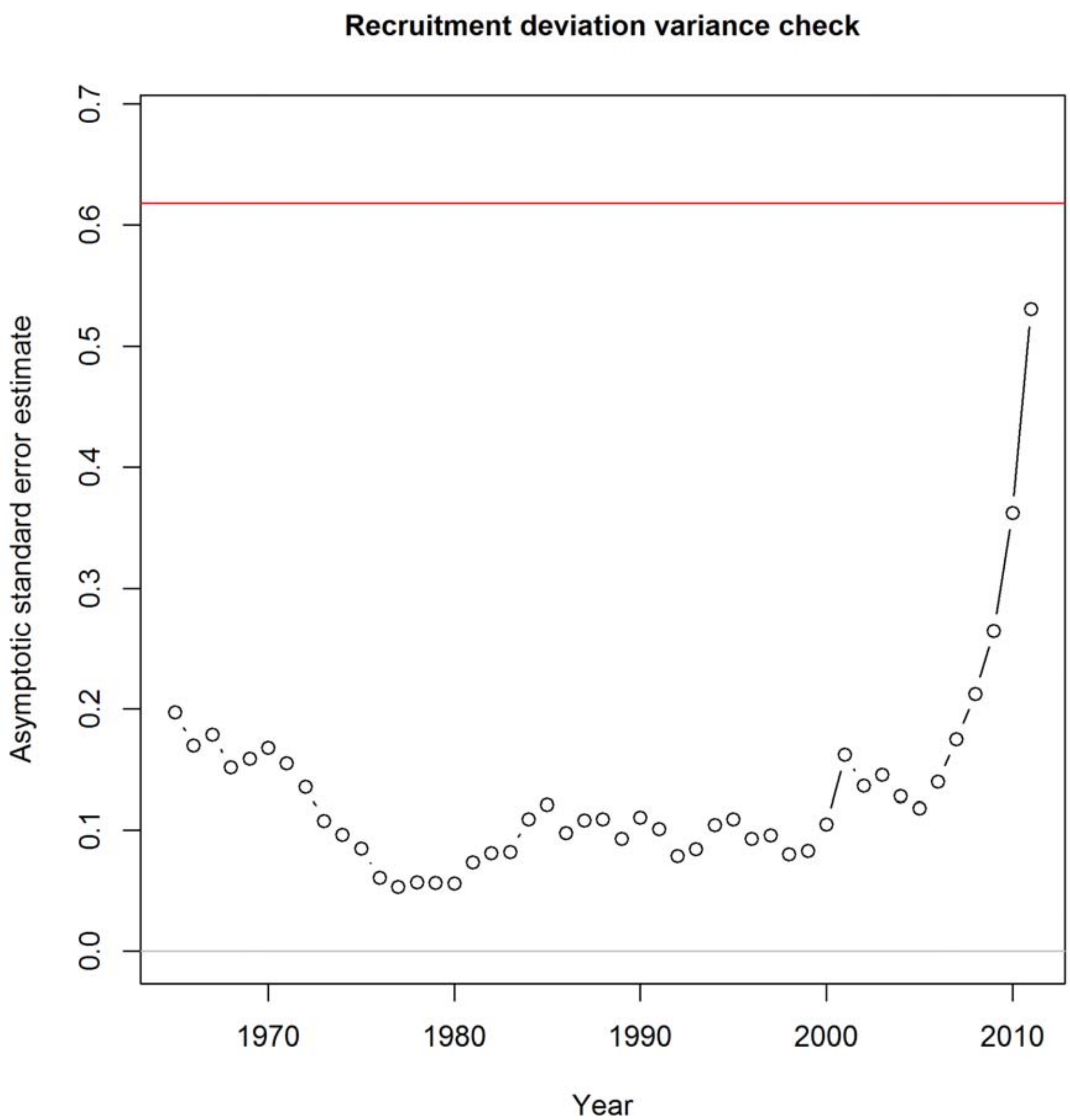


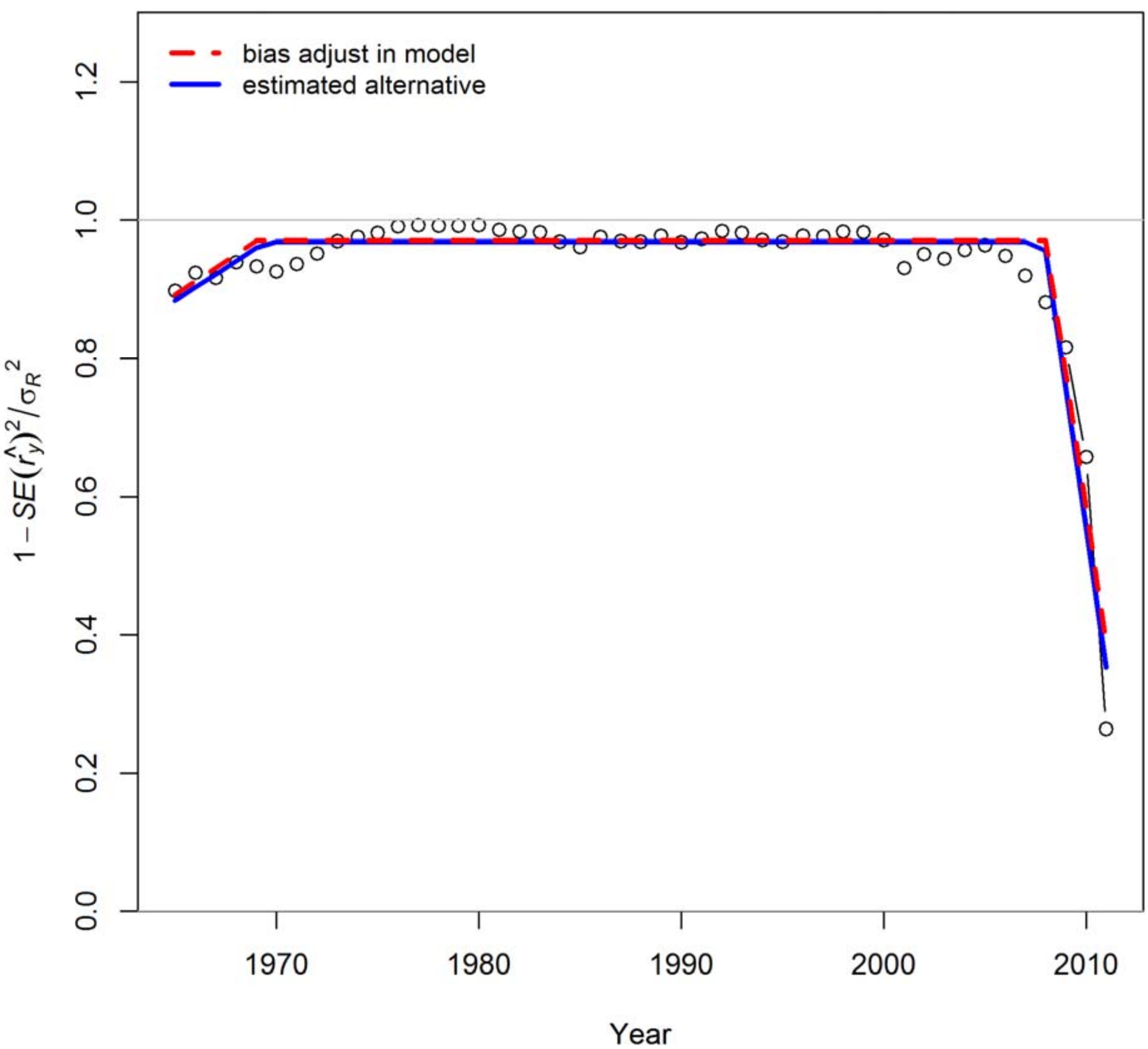
Middle of year expected numbers at length in thousands (max=5122360)
Length
Year
20
15
10
5
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010



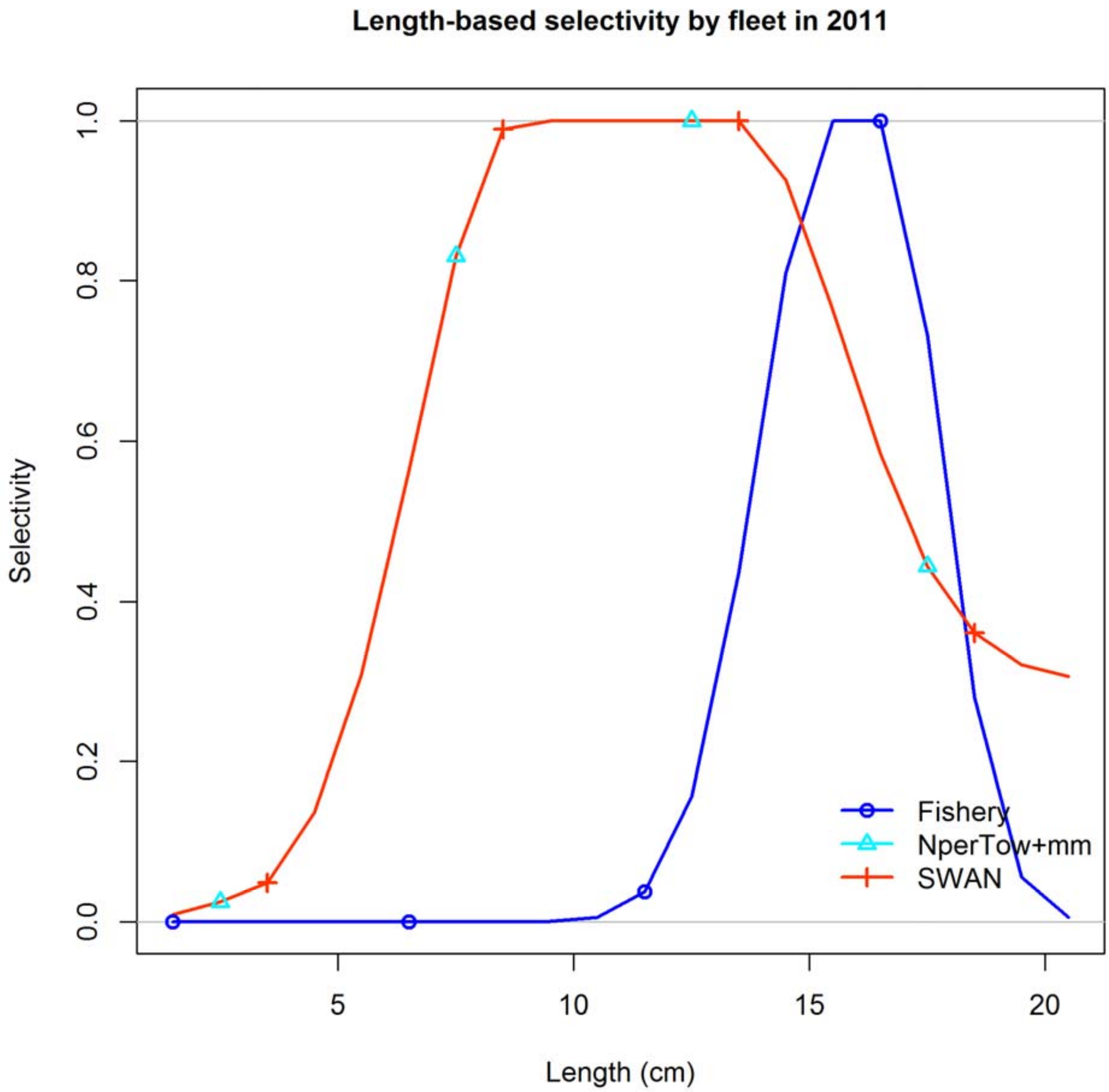
Log recruitment deviation
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1970
1980
1990
2000
2010
Year

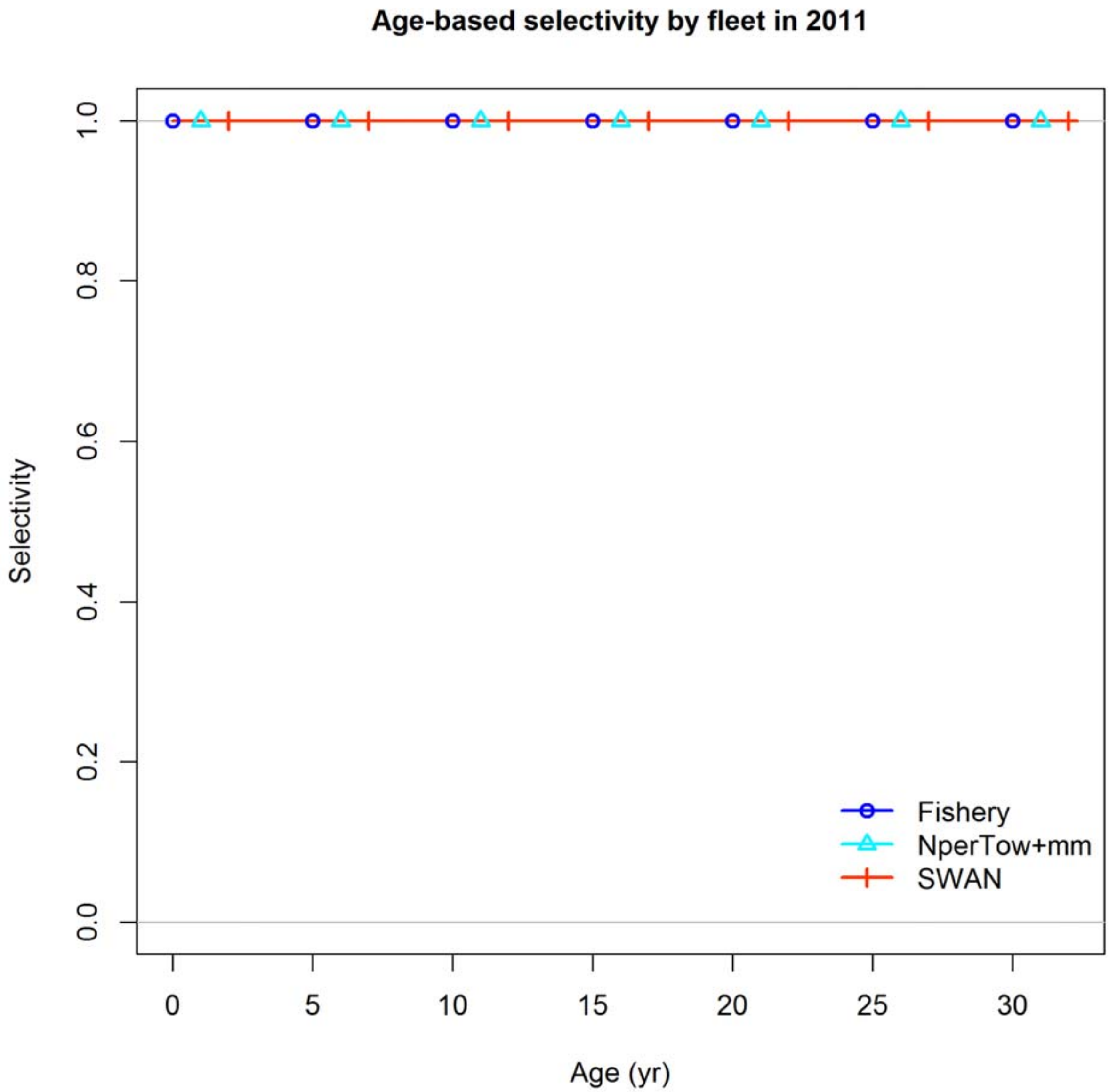

Log recruitment deviation
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1970
1980
1990
2000
2010
Year

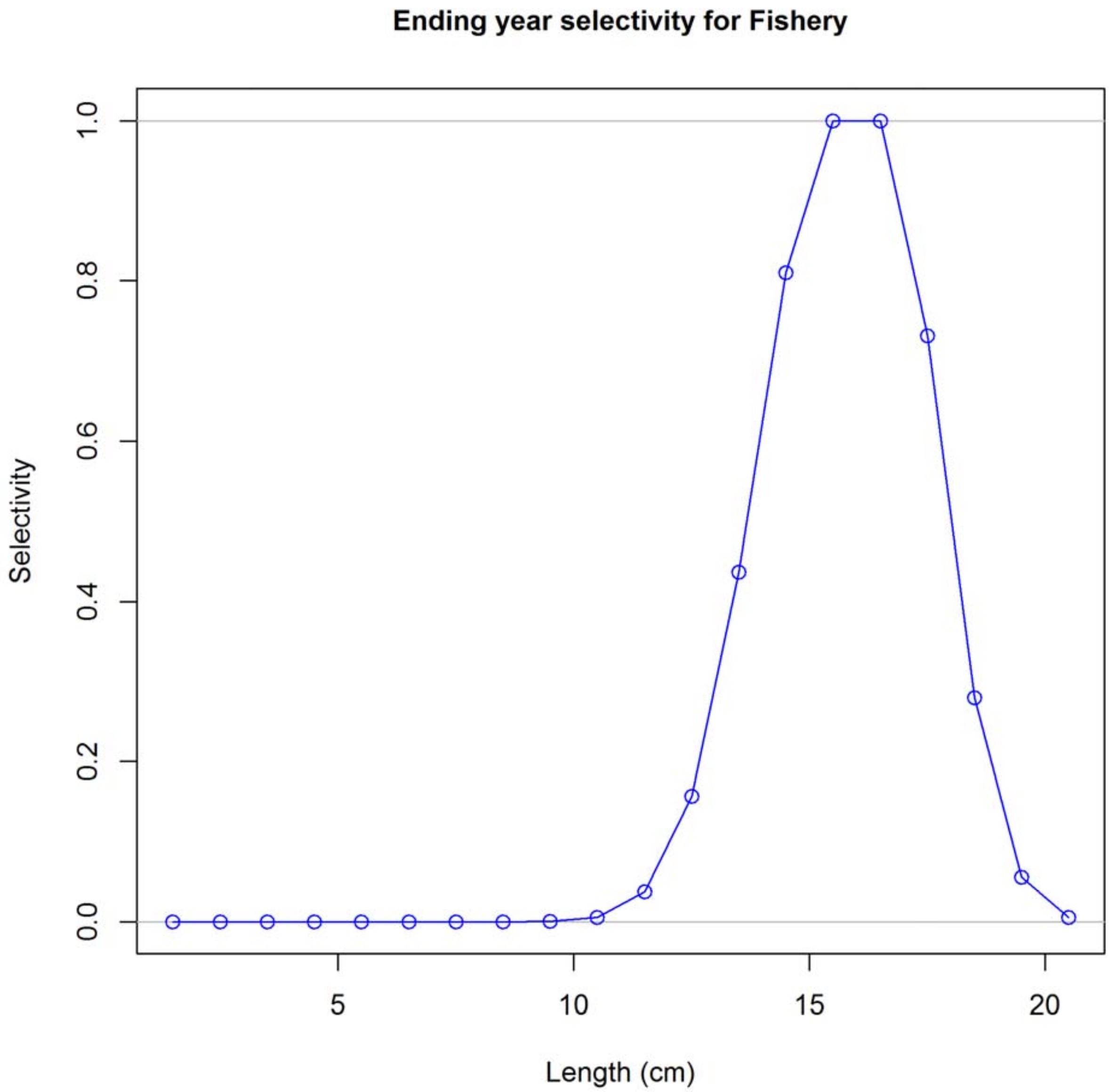

Recruitment deviation variance check
Asymptotic standard error estimate
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
1970
1980
1990
2000
2010
Year

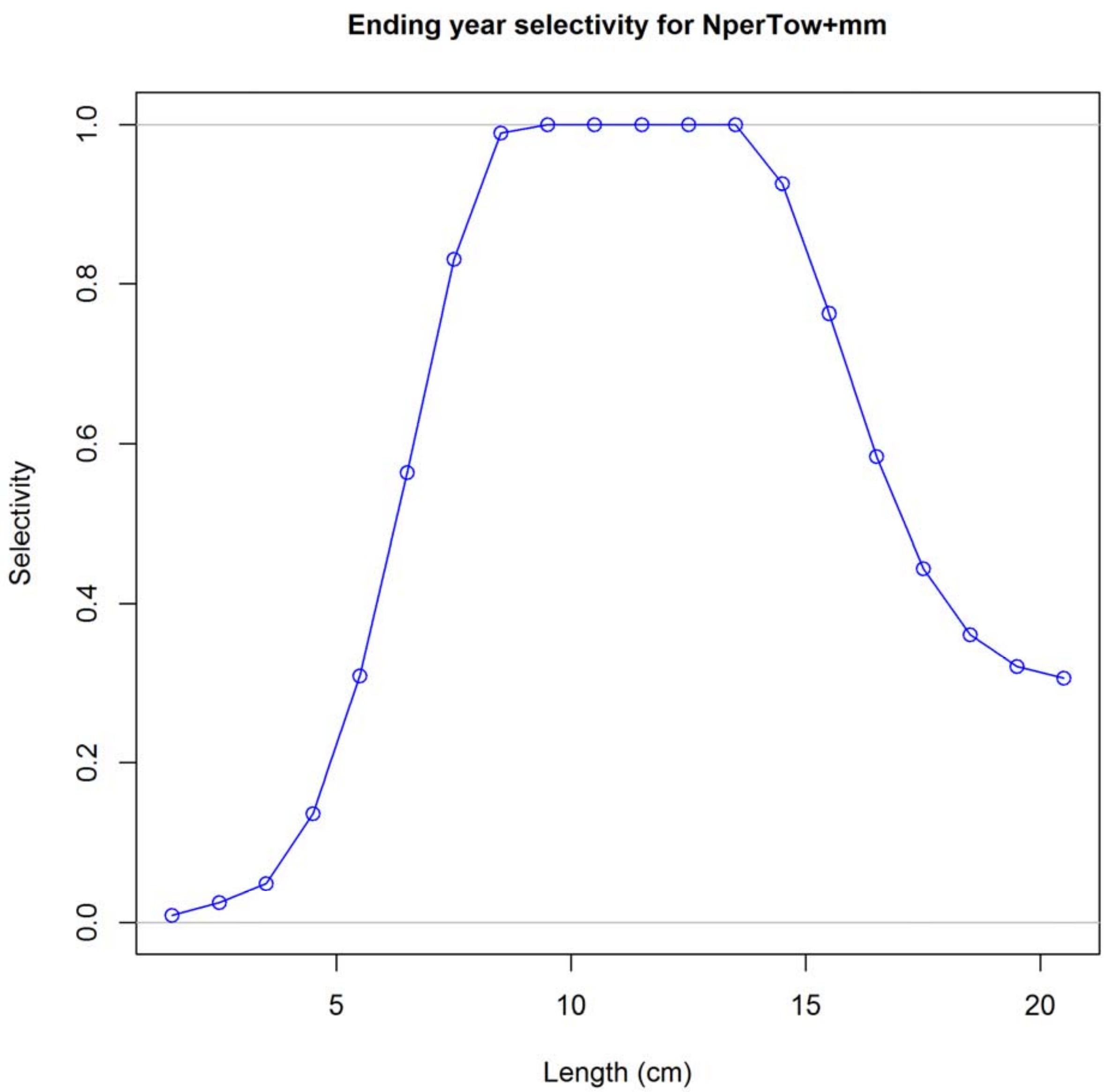


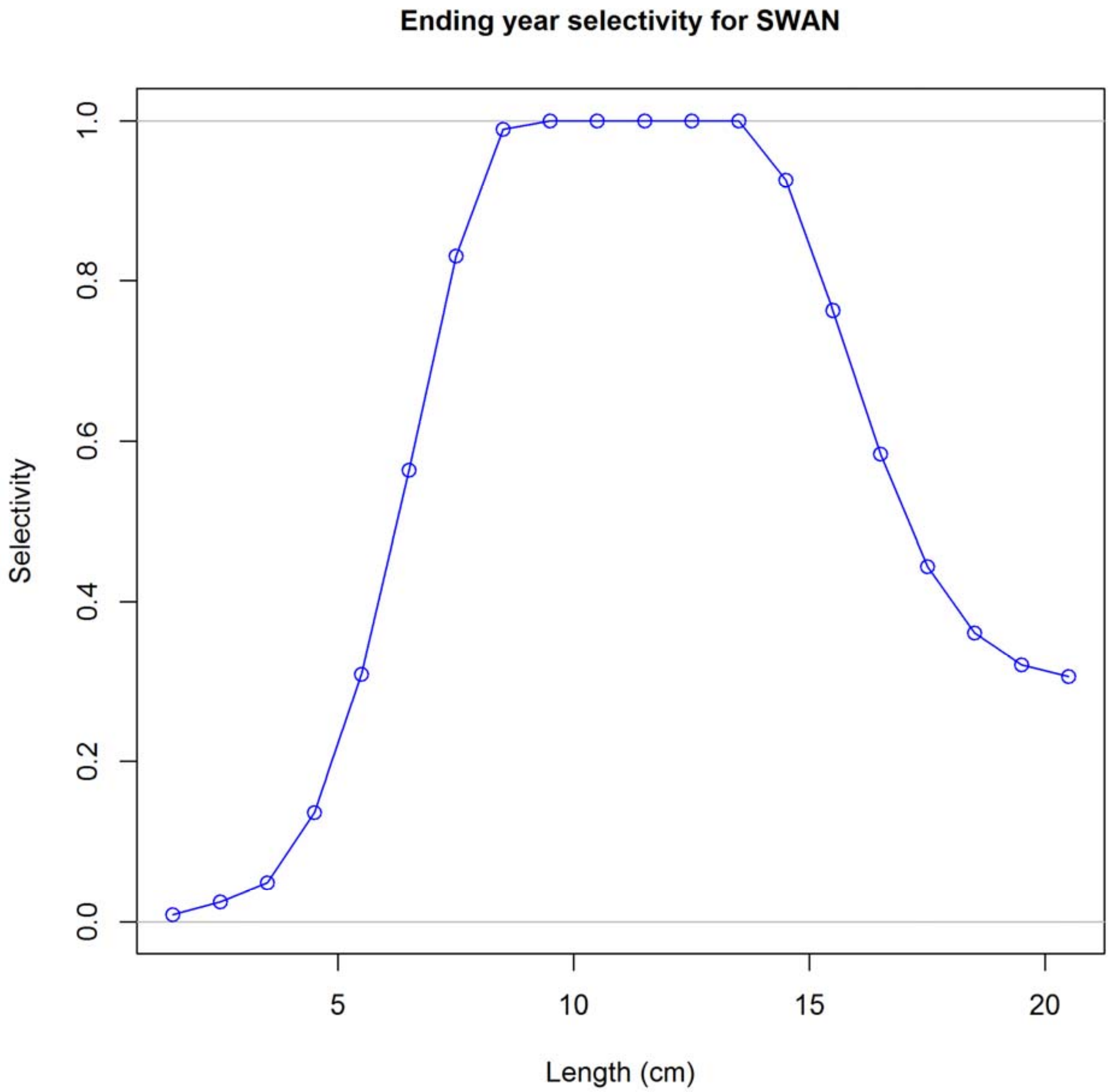
bias adjust in model
estimated alternative
$1 - SE(\hat{r}_y)^2/\sigma_R^2$
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1970
1980
1990
2000
2010
Year


Length-based selectivity by fleet in 2011
Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
Length (cm)
Fishery
NperTow+mm
SWAN

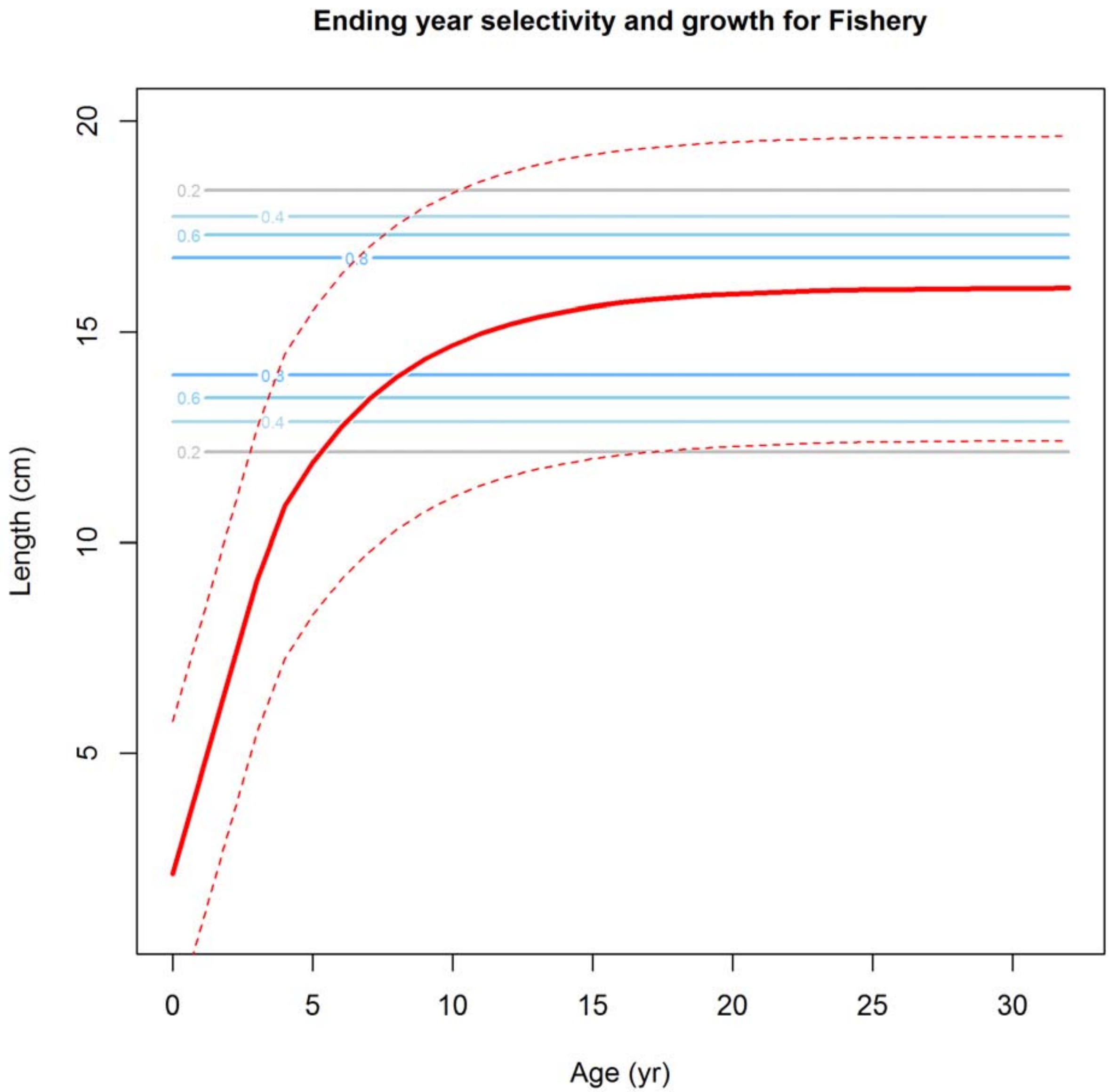

Age-based selectivity by fleet in 2011
Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
0
5
10
15
20
25
30
Age (yr)
Fishery
NperTow+mm
SWAN

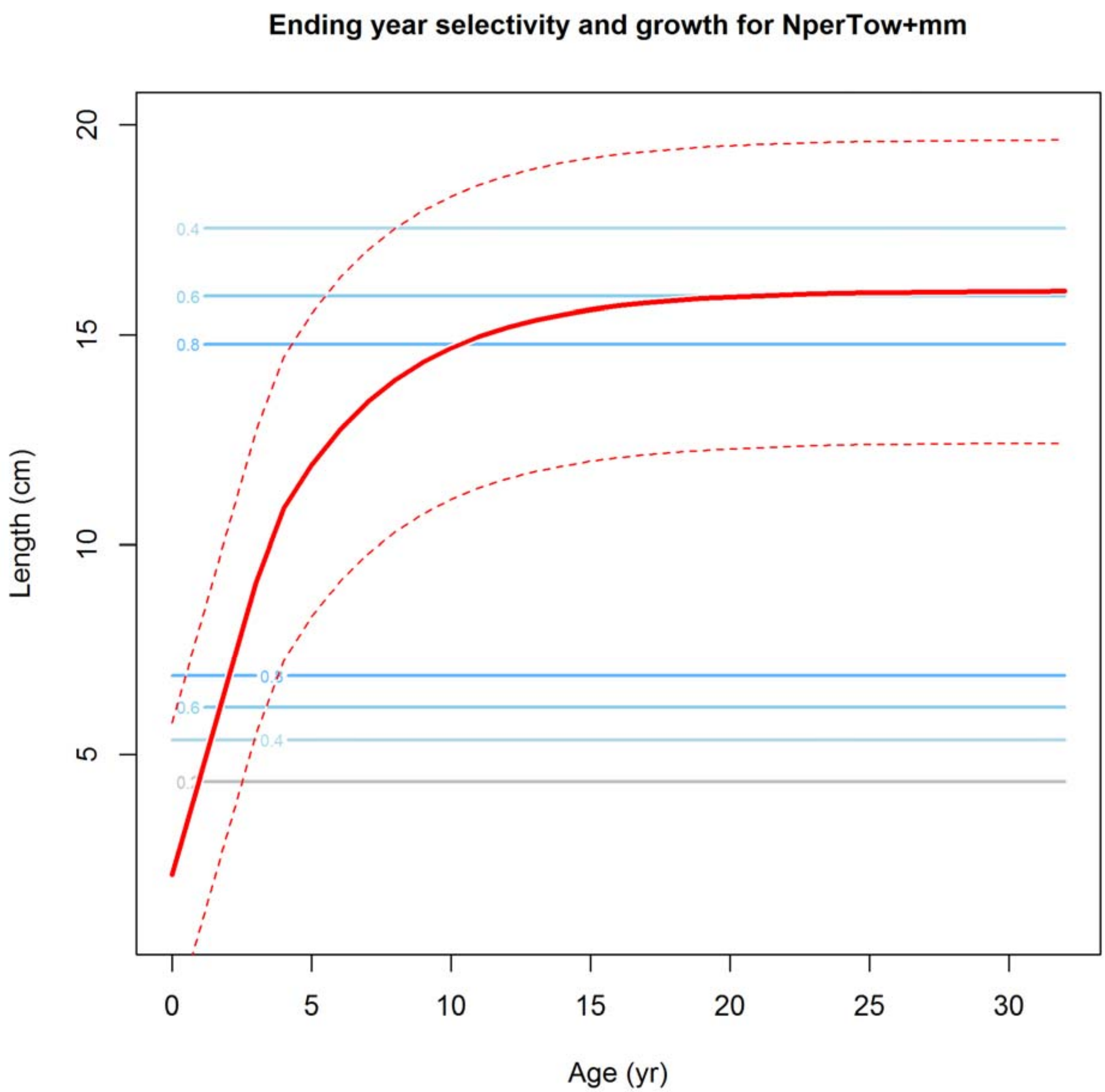

Ending year selectivity for Fishery
Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
Length (cm)


Ending year selectivity for NperTow+mm
Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
Length (cm)

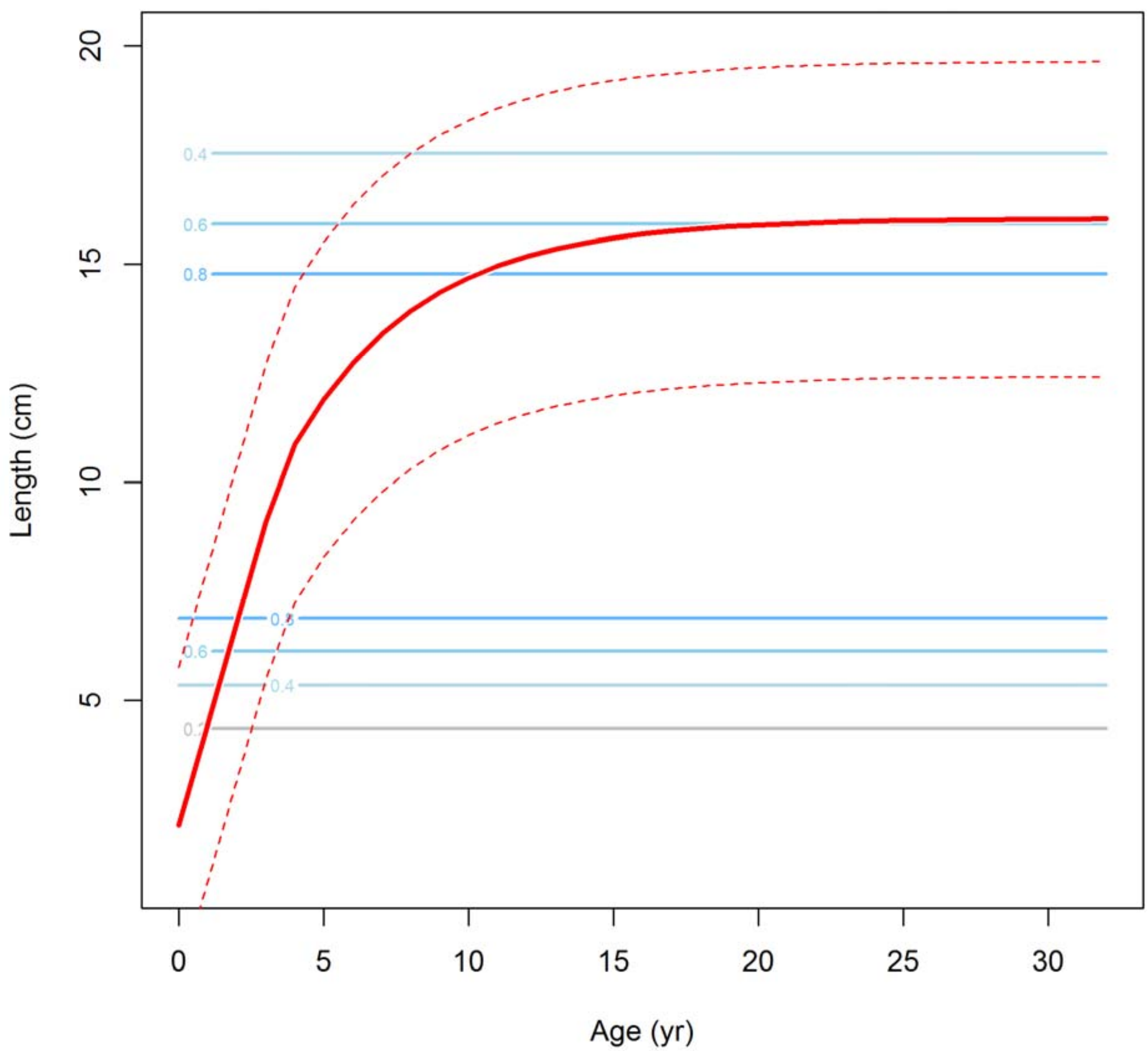


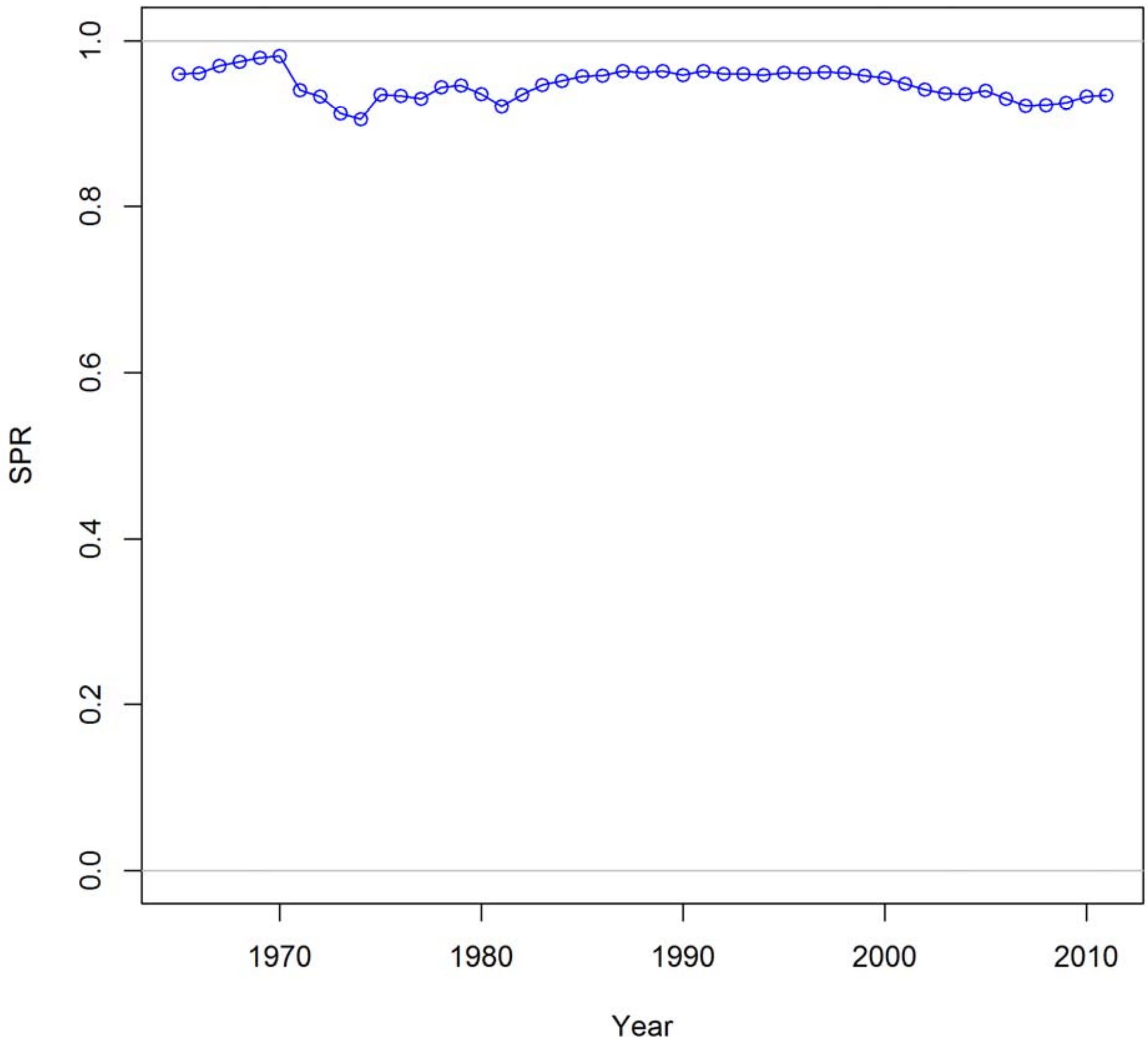
Ending year selectivity for SWAN
Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
Length (cm)

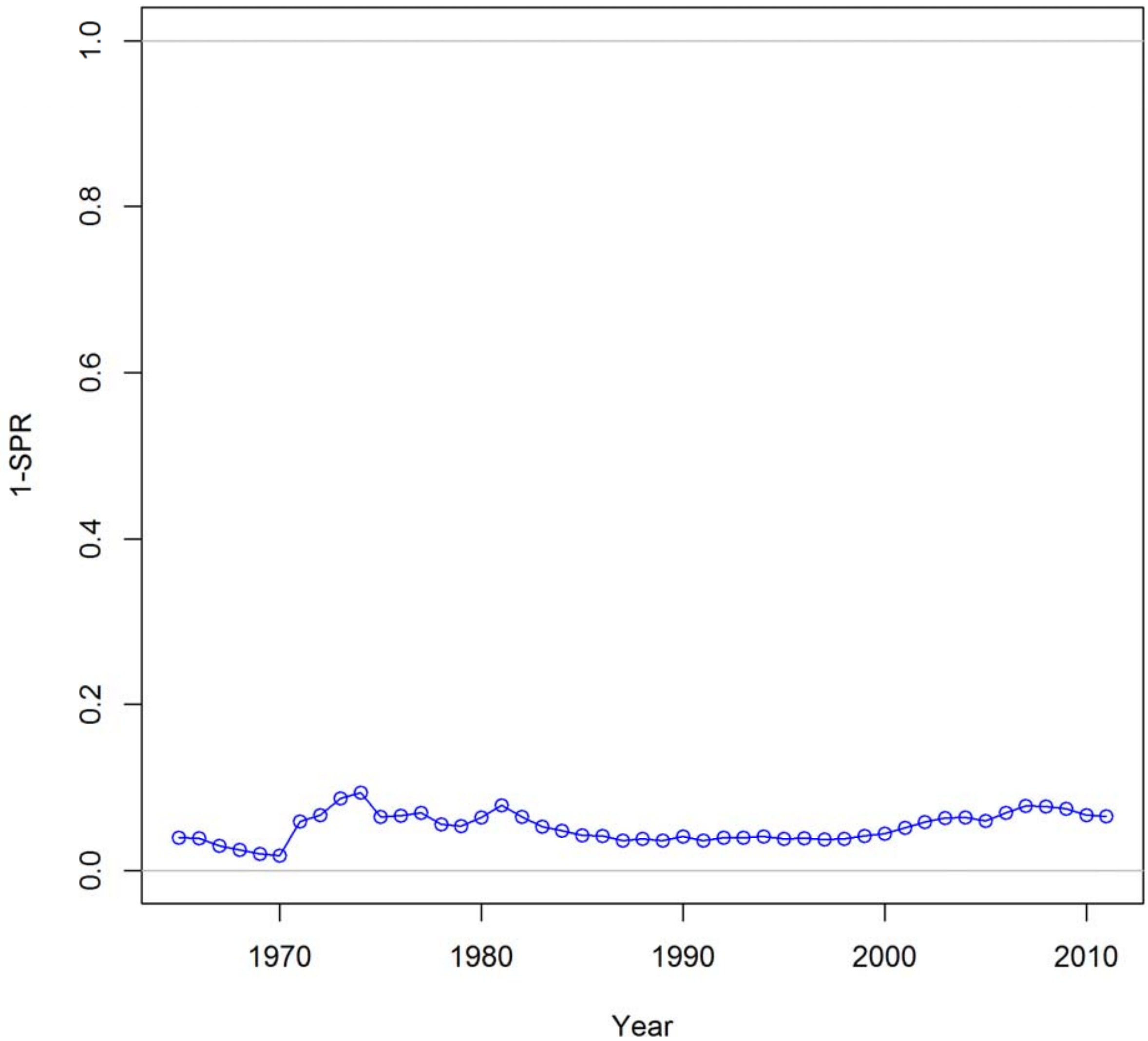

Ending year selectivity and growth for Fishery
Length (cm)
Age (yr)
20
15
10
5
0
5
10
15
20
25
30
0.2
0.4
0.6
0.8
0.8
0.6
0.4
0.2


Ending year selectivity and growth for NperTow+mm
Length (cm)
Age (yr)
0
5
10
15
20
25
30
5
10
15
20
0.4
0.6
0.8
0.8
0.6
0.4
0.2

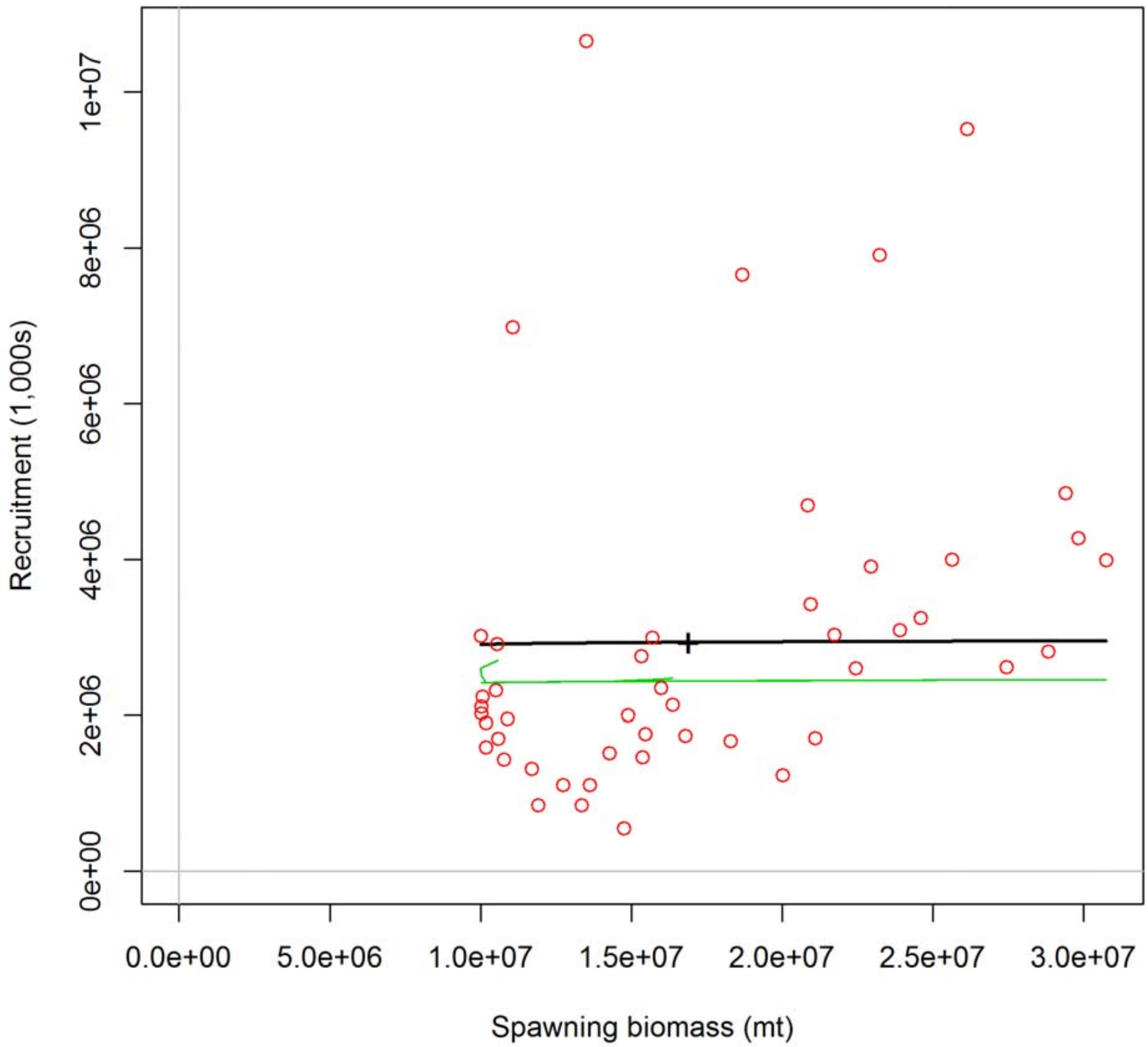
Ending year selectivity and growth for SWAN



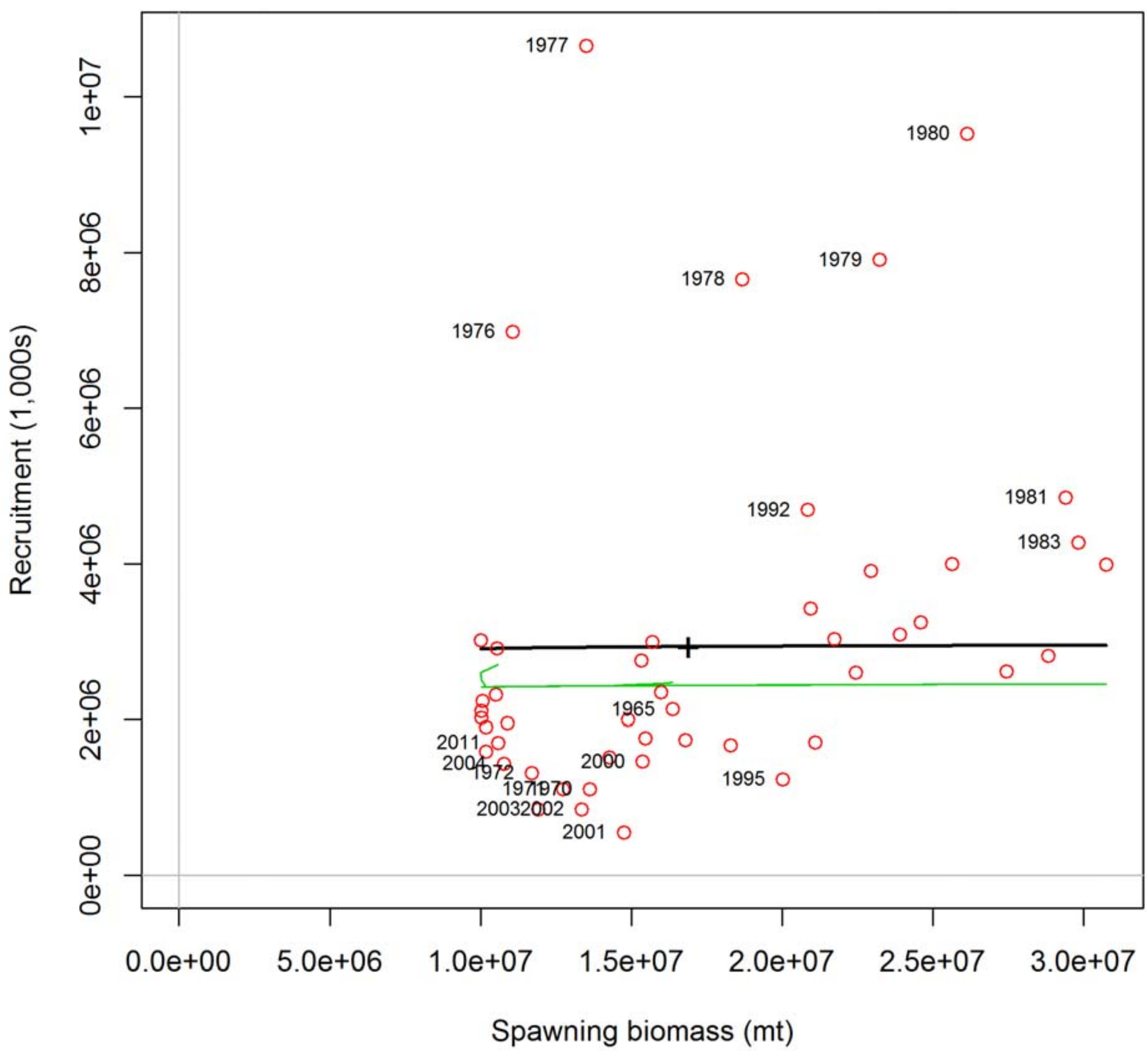

SPR
Year
1.0
0.8
0.6
0.4
0.2
0.0
1970
1980
1990
2000
2010



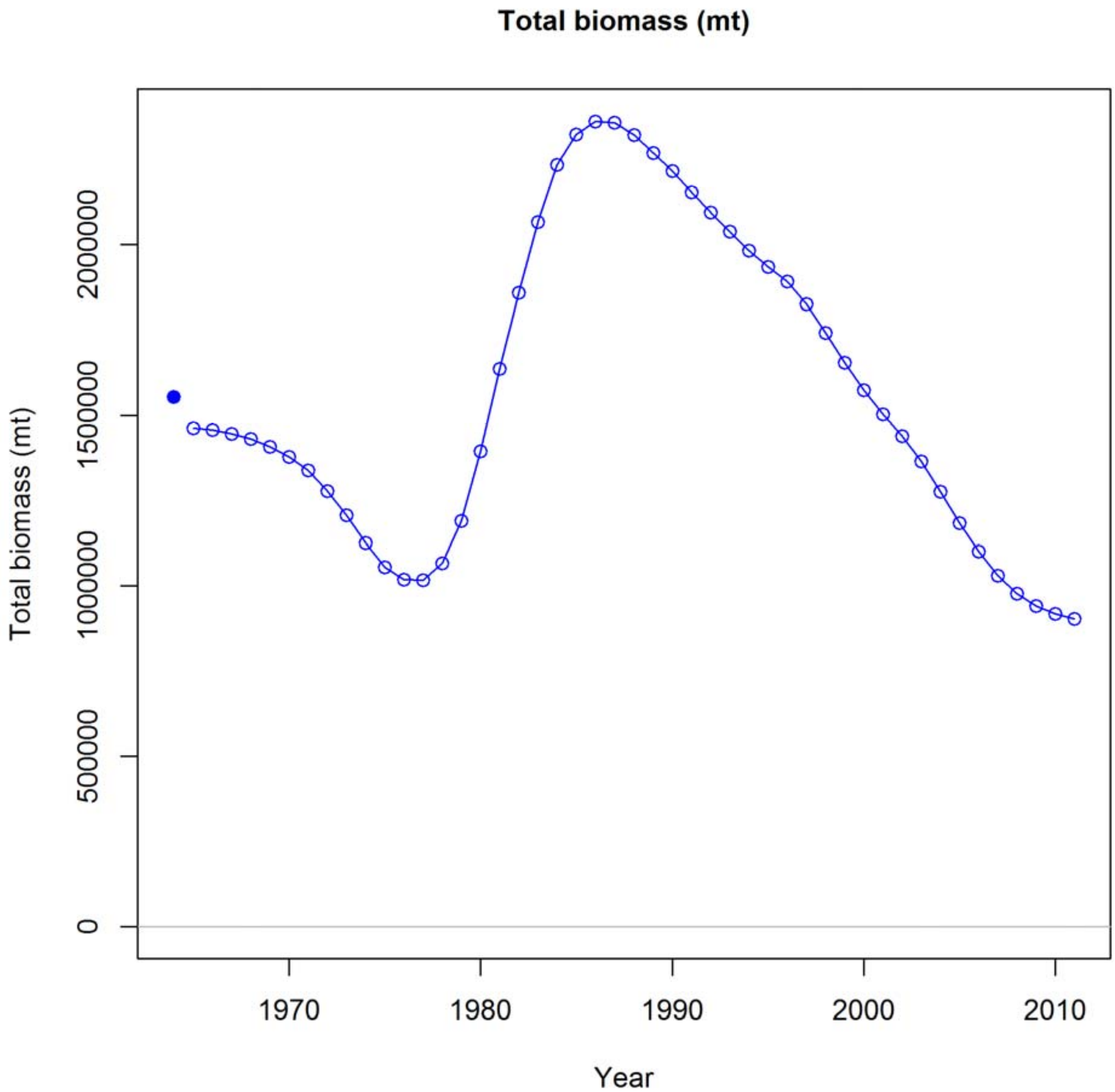
1-SPR
0.0
0.2
0.4
0.6
0.8
1.0
1970
1980
1990
2000
2010
Year



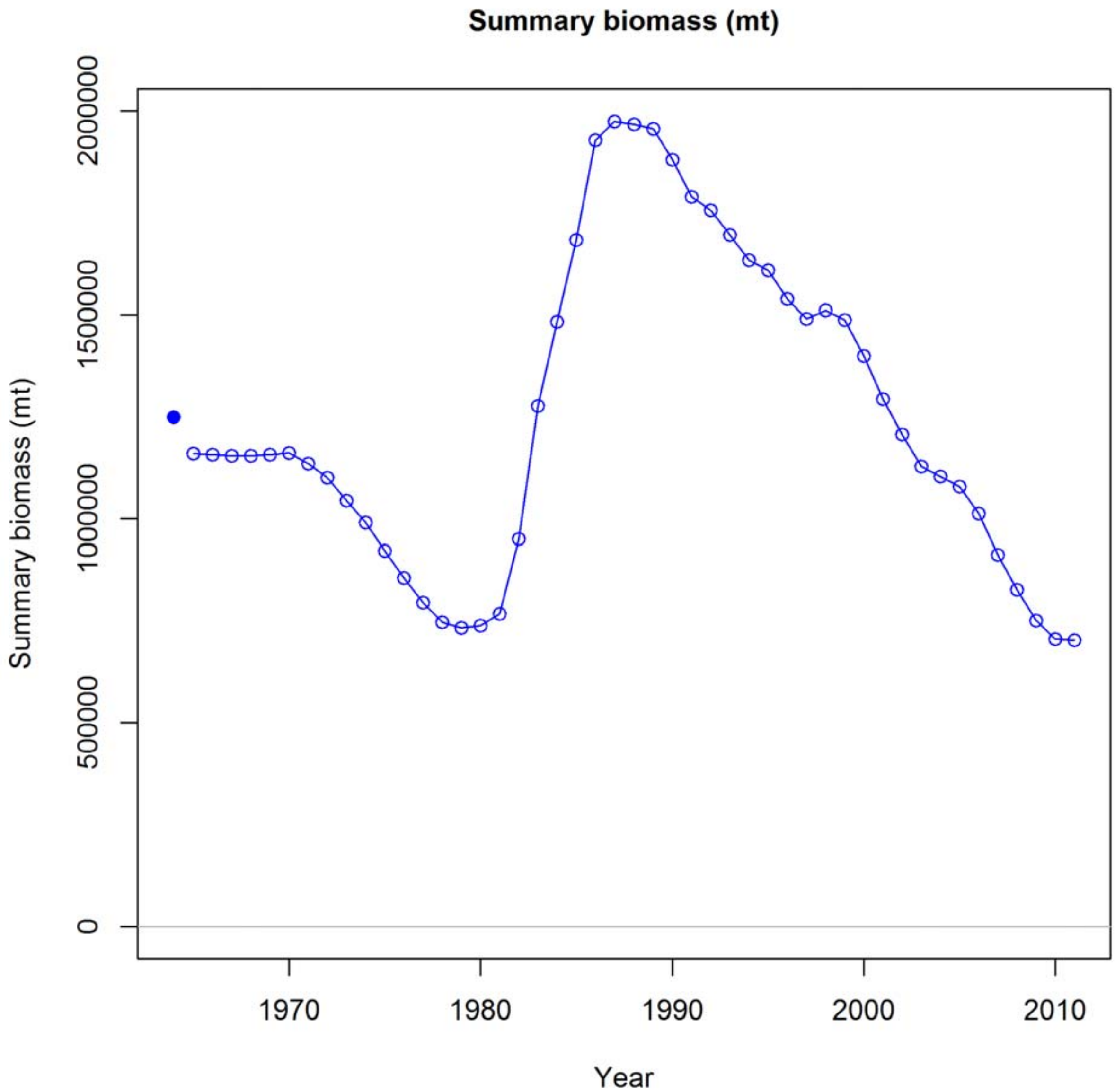
Recruitment (1,000s)
0e+00
2e+06
4e+06
6e+06
8e+06
1e+07
0.0e+00
5.0e+06
1.0e+07
1.5e+07
2.0e+07
2.5e+07
3.0e+07
Spawning biomass (mt)

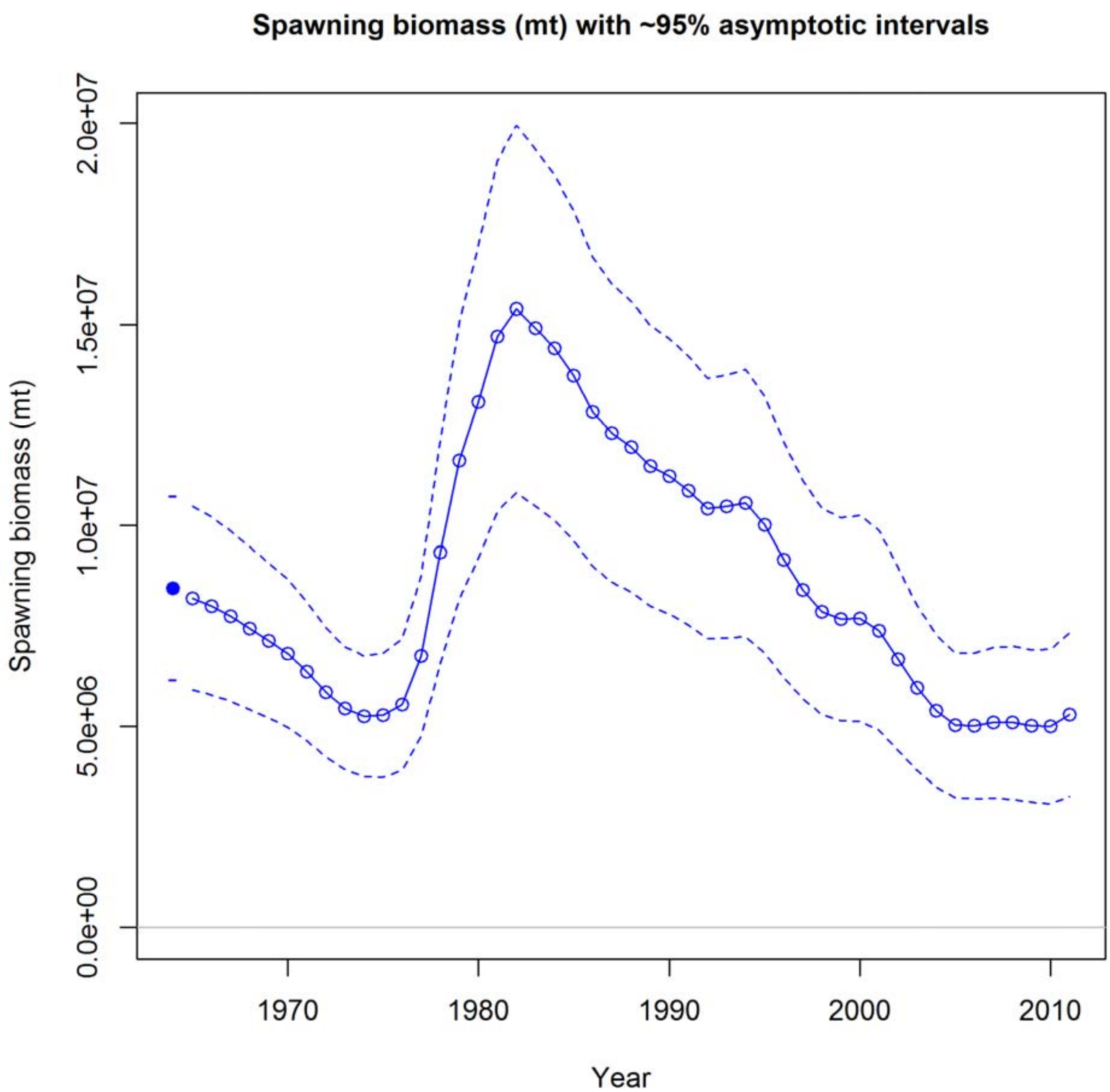


Recruitment (1,000s)
0e+00
2e+06
4e+06
6e+06
8e+06
1e+07
0.0e+00
5.0e+06
1.0e+07
1.5e+07
2.0e+07
2.5e+07
3.0e+07
Spawning biomass (mt)
1977
1980
1979
1978
1976
1992
1981
1983
1965
2011
2004
1972
2000
1971
1970
2003
2002
1995
2001

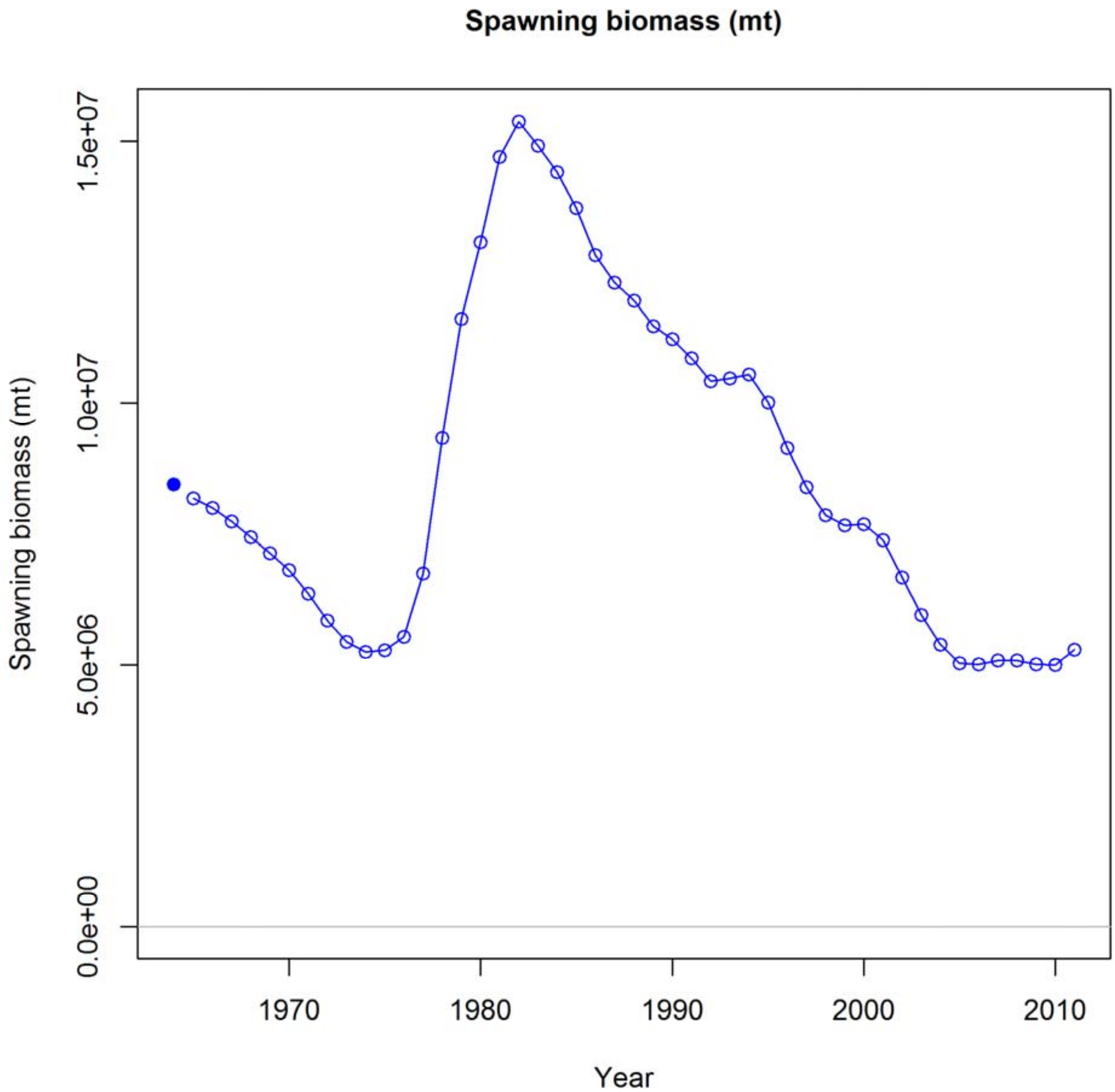


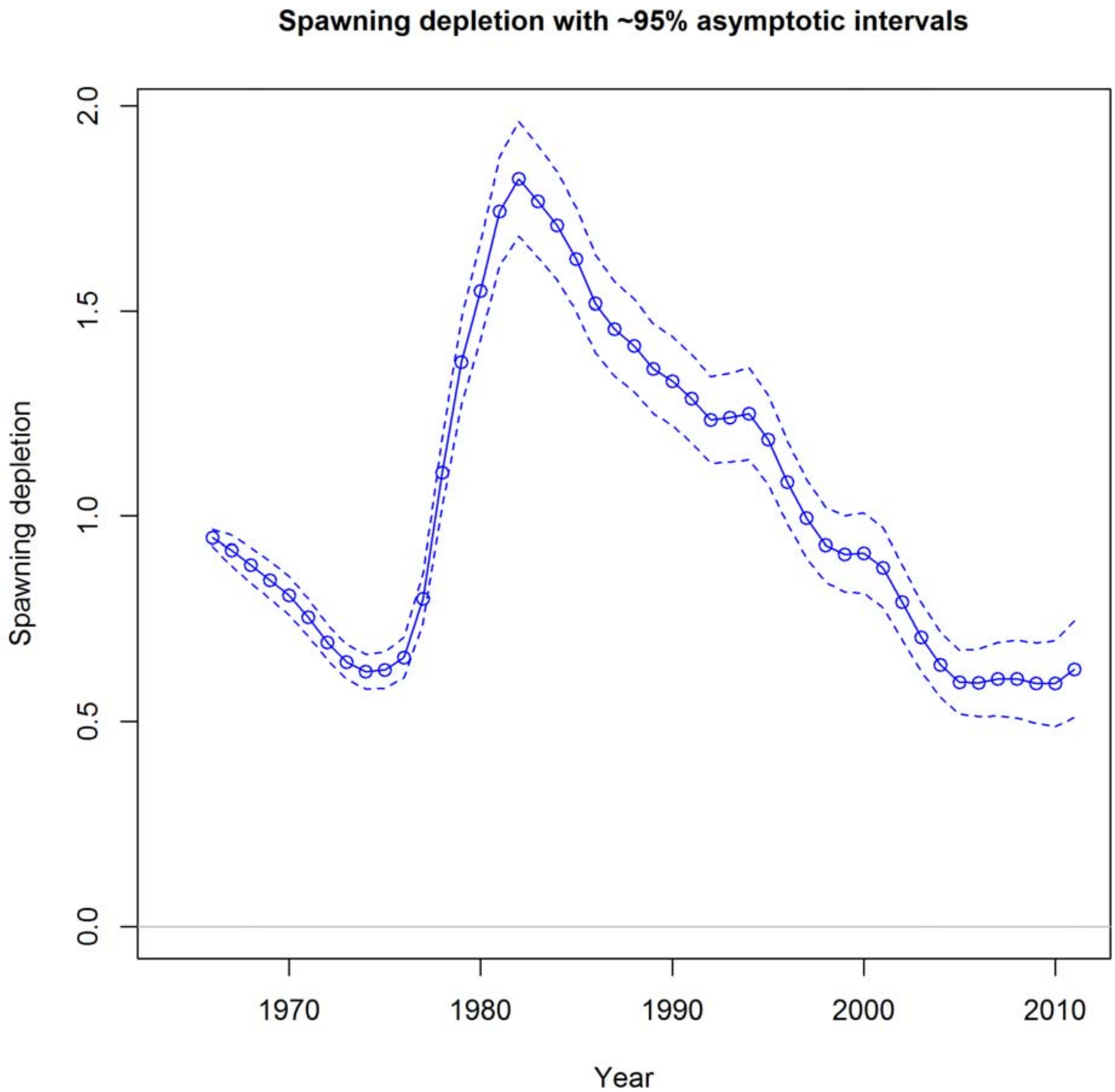
Total biomass (mt)
Total biomass (mt)
0
500000
1000000
1500000
2000000
1970
1980
1990
2000
2010
Year


Summary biomass (mt)
2000000
1500000
1000000
500000
0
Summary biomass (mt)
1970
1980
1990
2000
2010
Year

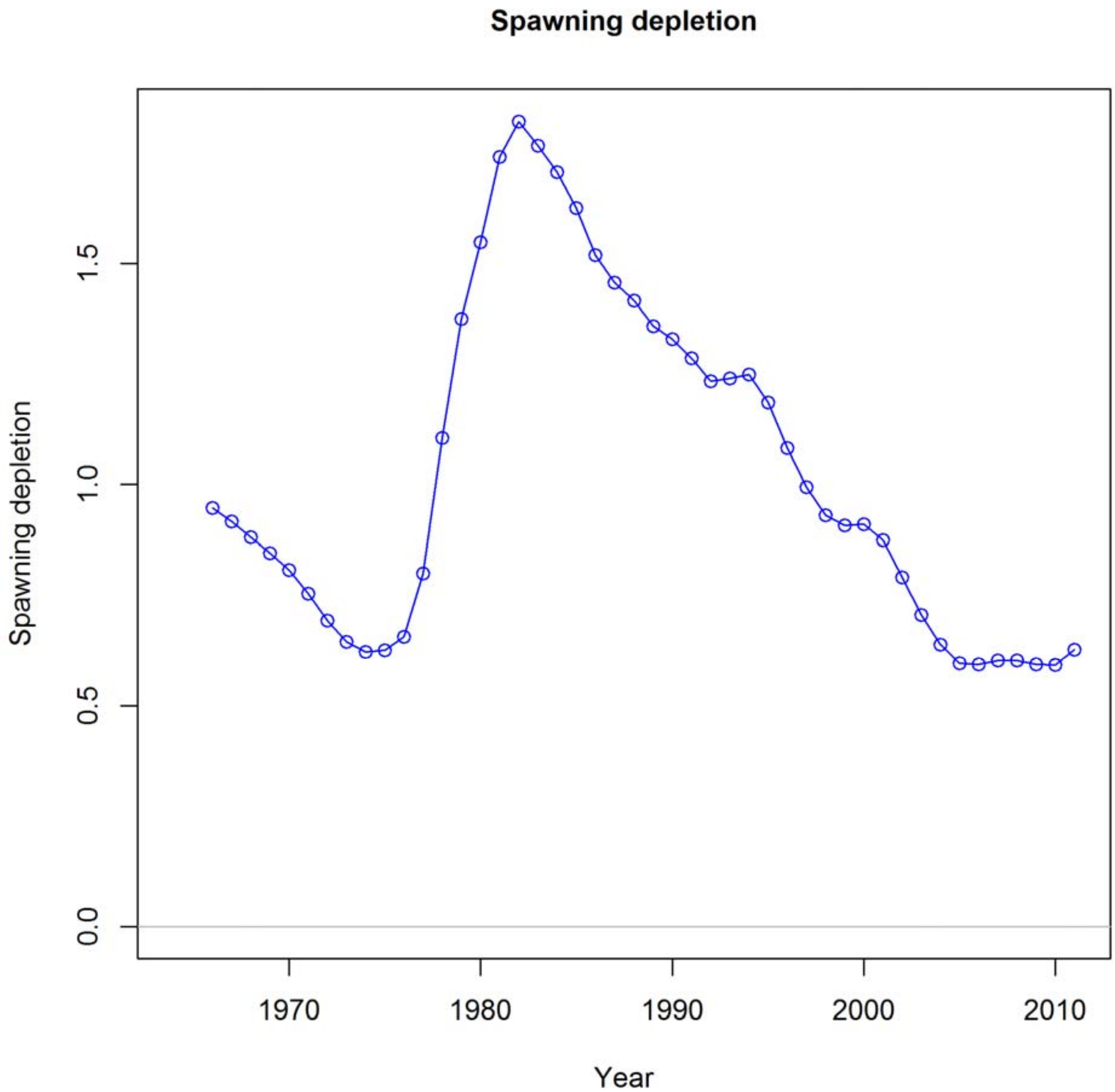


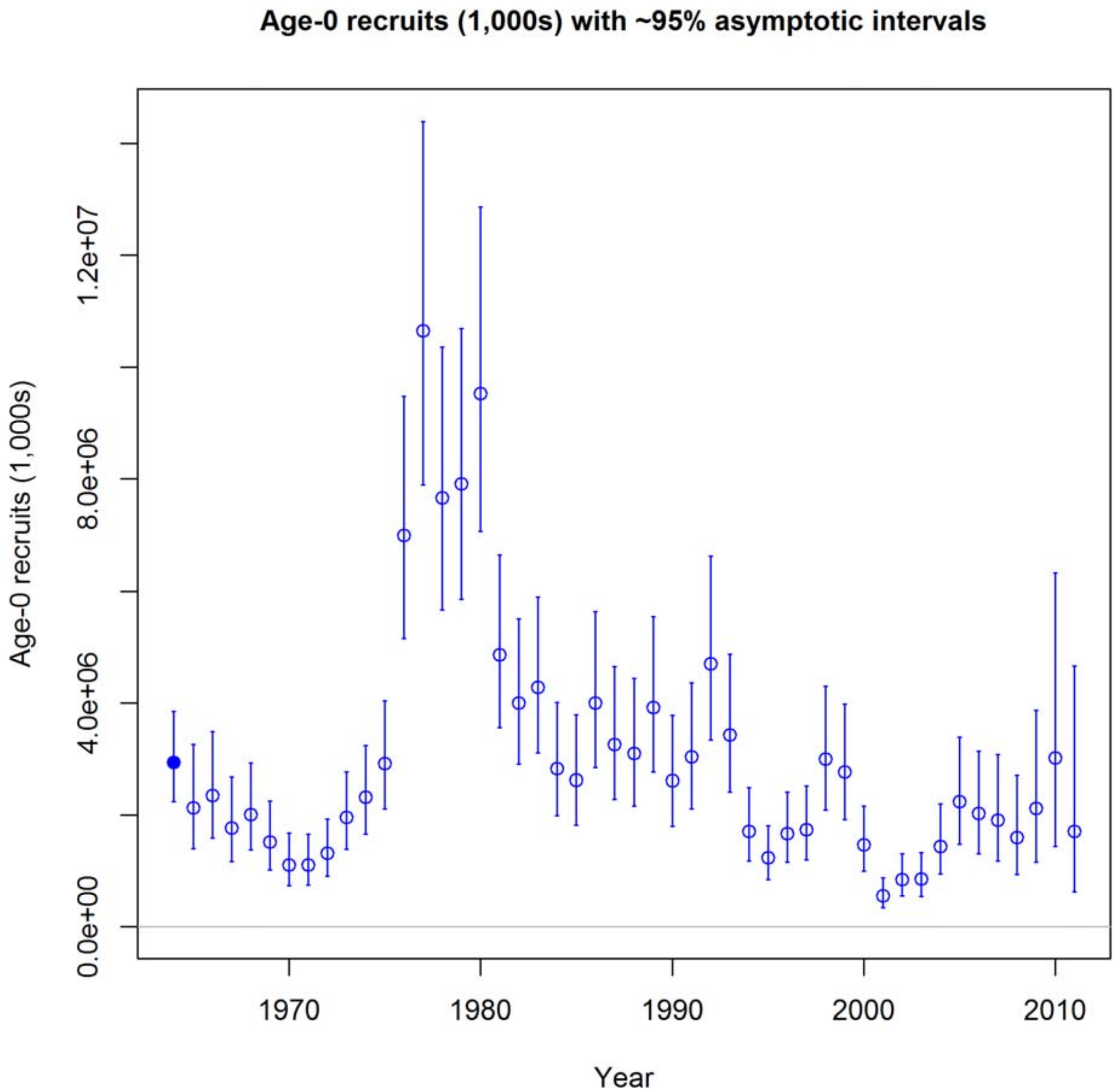
Spawning biomass (mt) with ~95% asymptotic intervals
Spawning biomass (mt)
0.0e+00
5.0e+06
1.0e+07
1.5e+07
2.0e+07
1970
1980
1990
2000
2010
Year

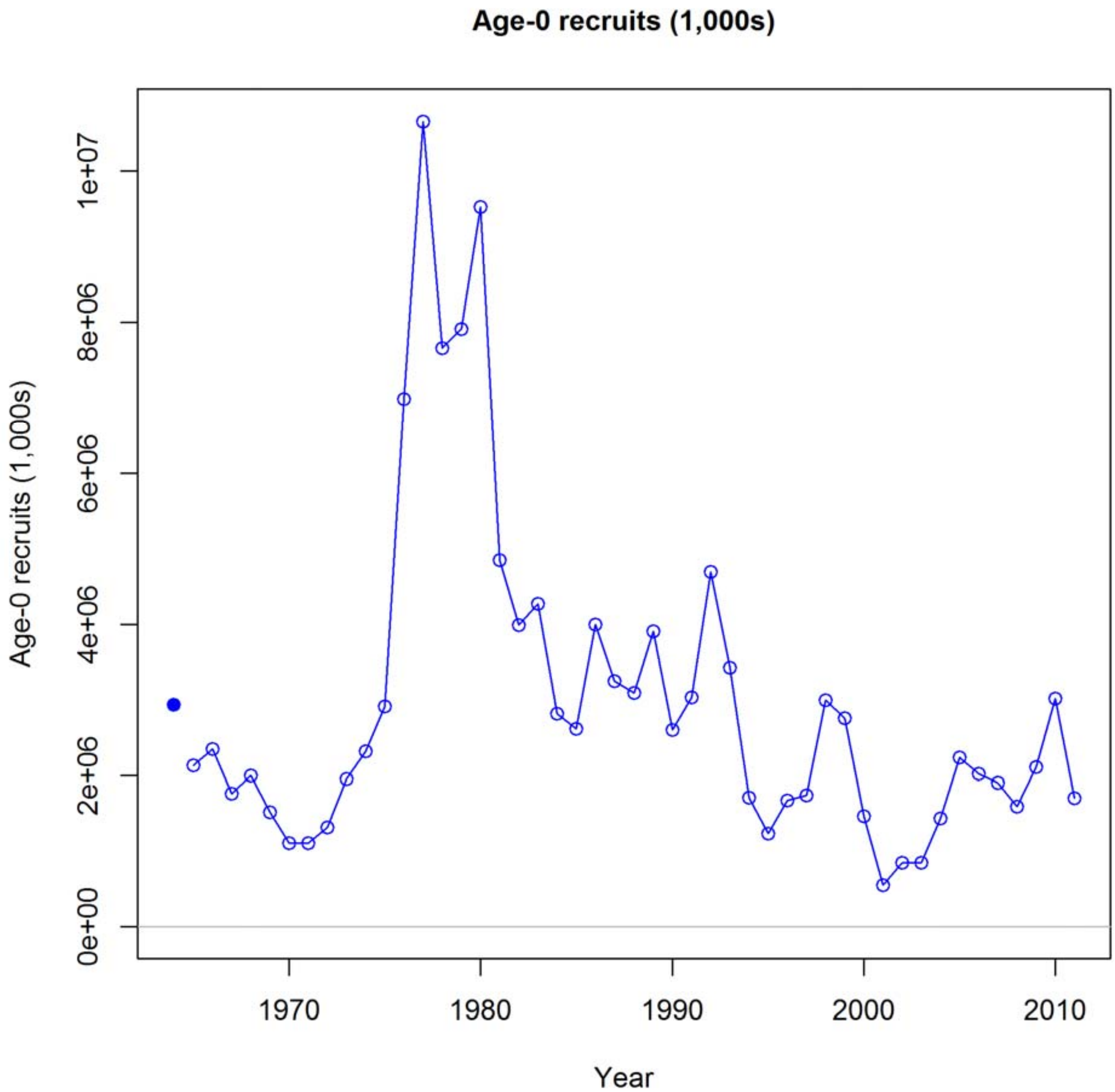

Spawning biomass (mt)
Spawning biomass (mt)
0.0e+00
5.0e+06
1.0e+07
1.5e+07
1970
1980
1990
2000
2010
Year

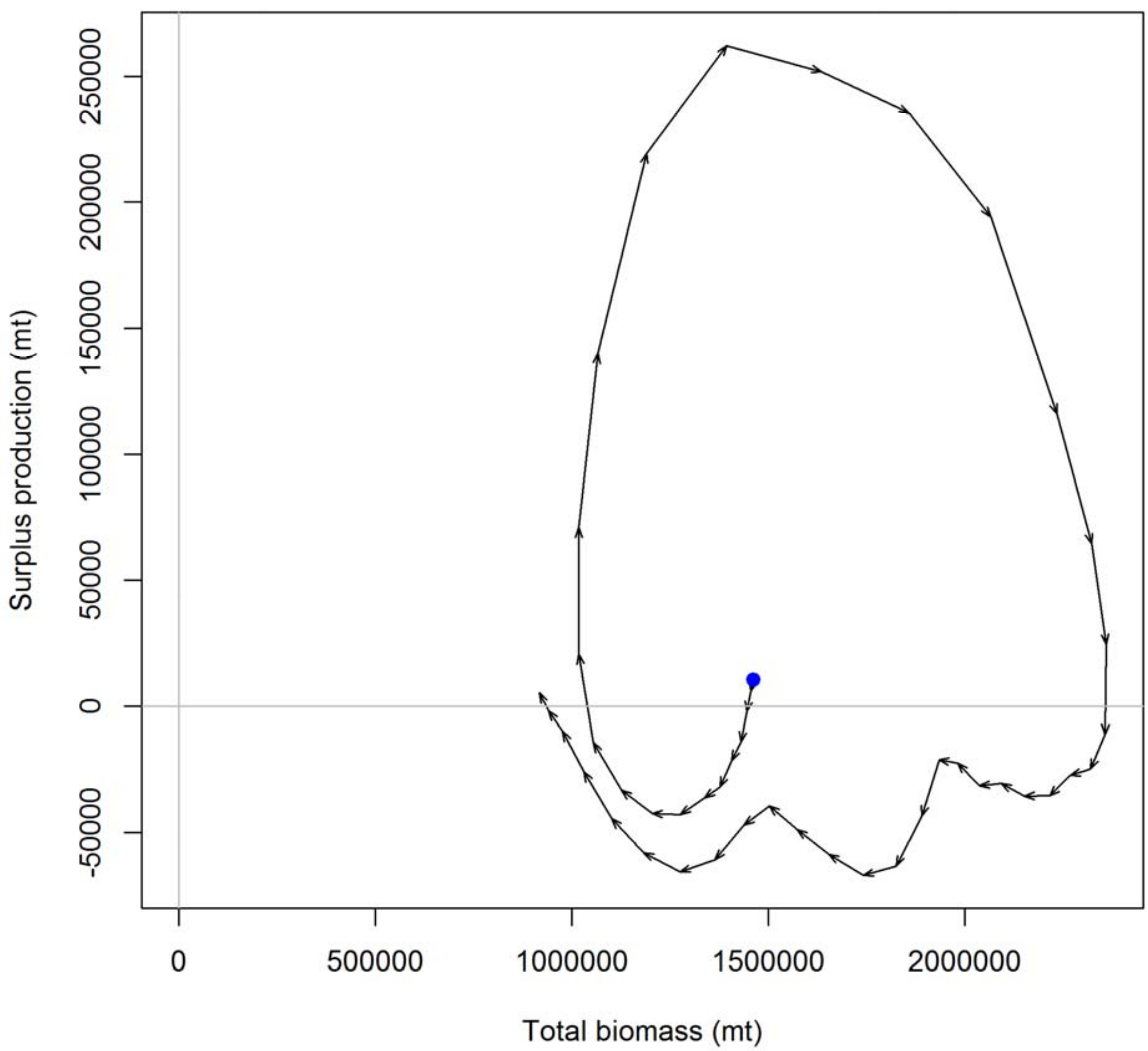


Spawning depletion with ~95% asymptotic intervals
Spawning depletion
Year
0.0
0.5
1.0
1.5
2.0
1970
1980
1990
2000
2010


Spawning depletion
Spawning depletion
0.0
0.5
1.0
1.5
1970
1980
1990
2000
2010
Year

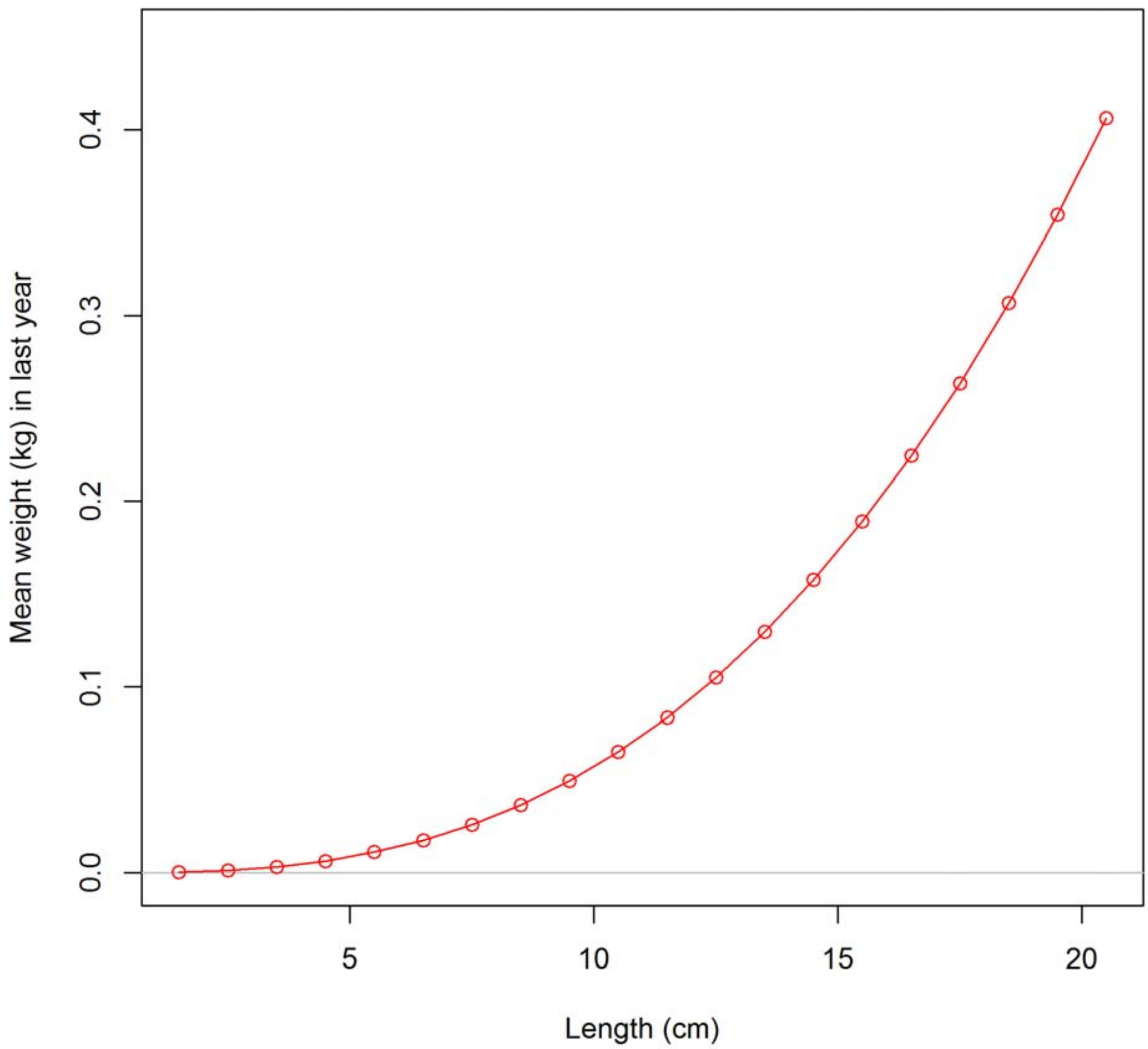

Age-0 recruits (1,000s) with ~95% asymptotic intervals
Age-0 recruits (1,000s)
0.0e+00
4.0e+06
8.0e+06
1.2e+07
1970
1980
1990
2000
2010
Year

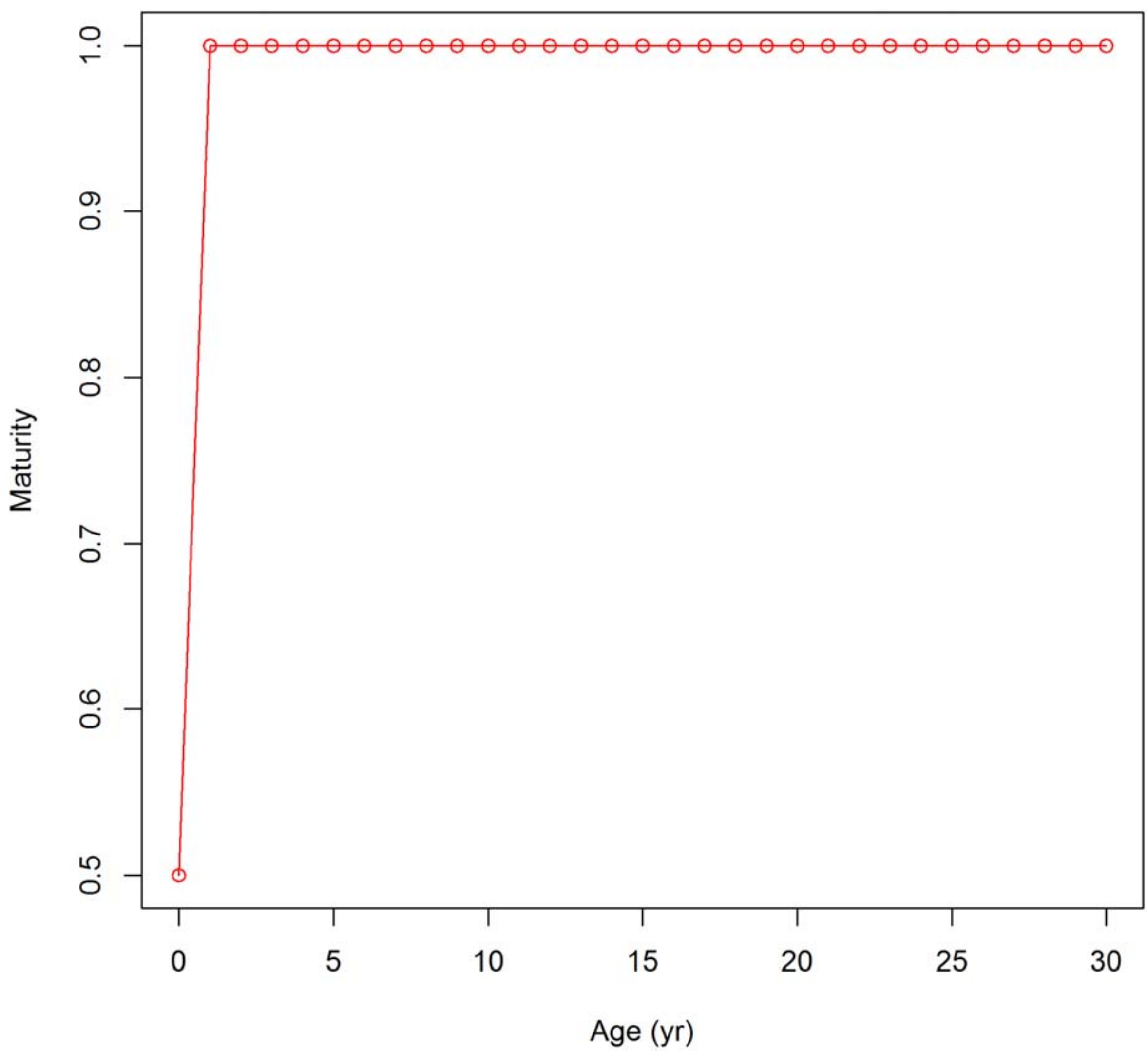

Age-0 recruits (1,000s)
Age-0 recruits (1,000s)
0e+00
2e+06
4e+06
6e+06
8e+06
1e+07
1970
1980
1990
2000
2010
Year


Surplus production (mt)
250000
200000
150000
100000
50000
0
-50000
0
500000
1000000
1500000
2000000
Total biomass (mt)

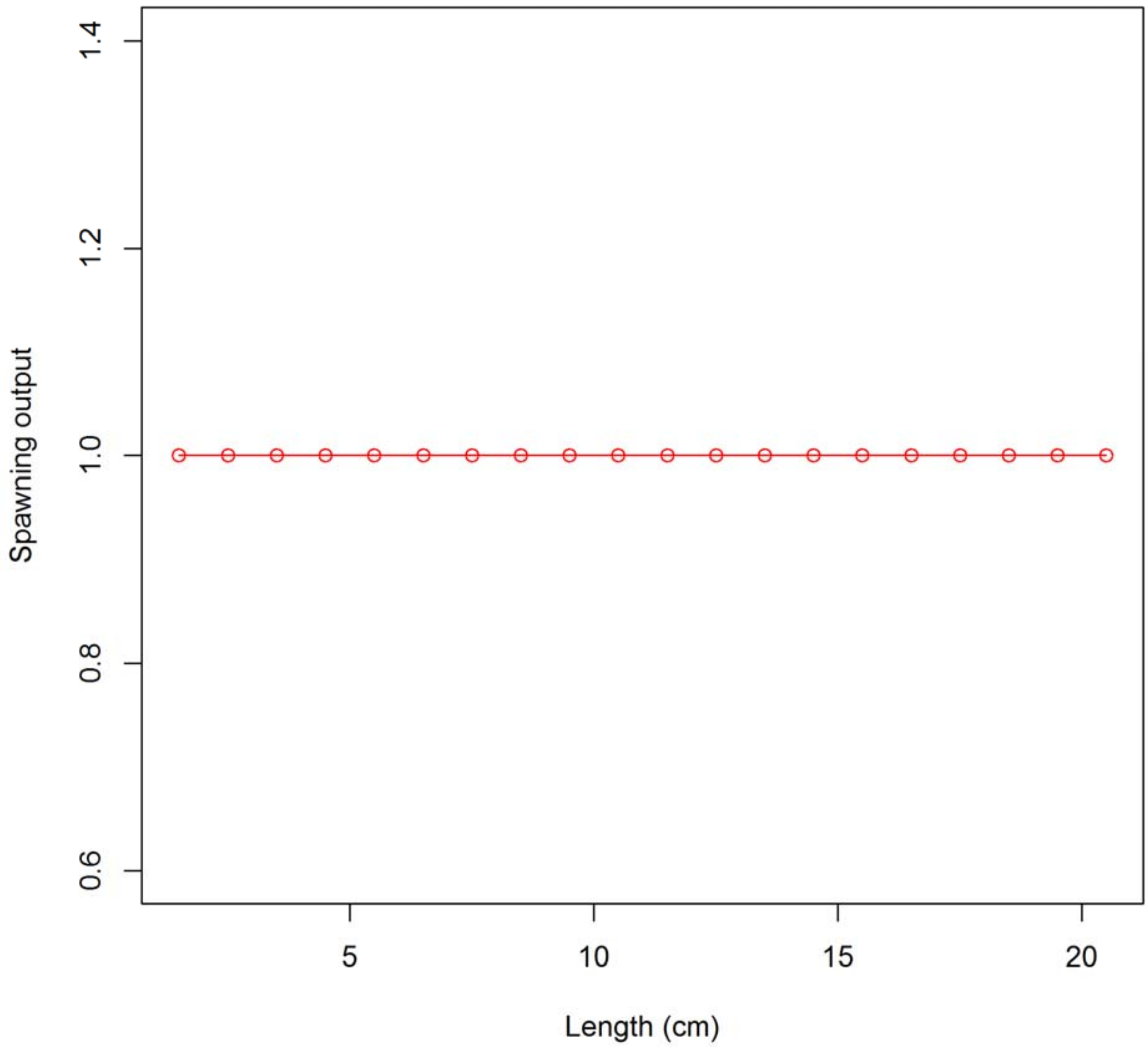
Appendix A7: SS3 Diagnostics for the GBK area

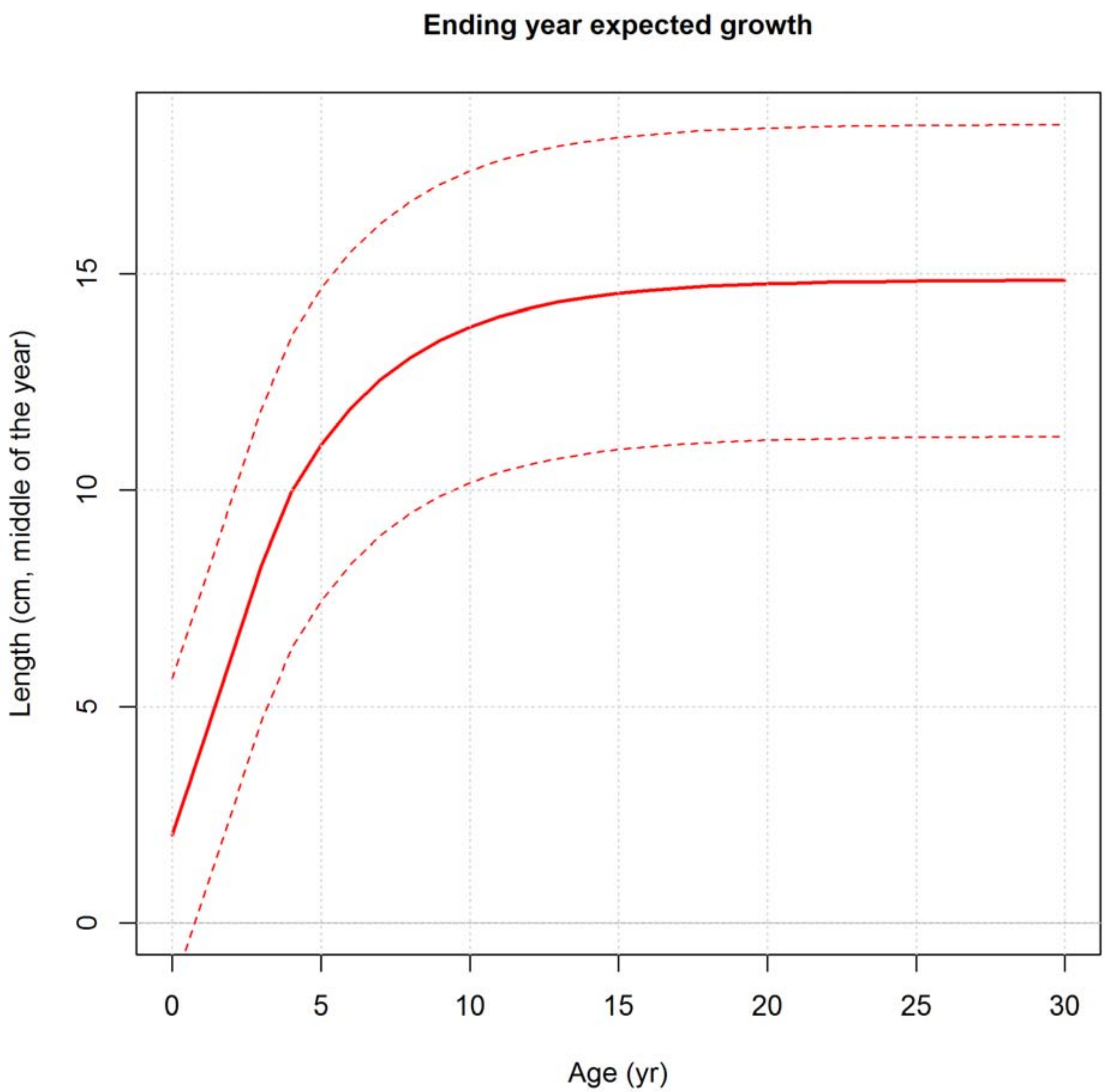
Plots created using the 'r4ss' package in R
Stock Synthesis version: SS−V3.24f
StartTime: Wed Jan 16 11:47:53 2013
Data_File: Surfclam_GBK−1.dat
Control_File: Surfclam_GBK−1.ctl

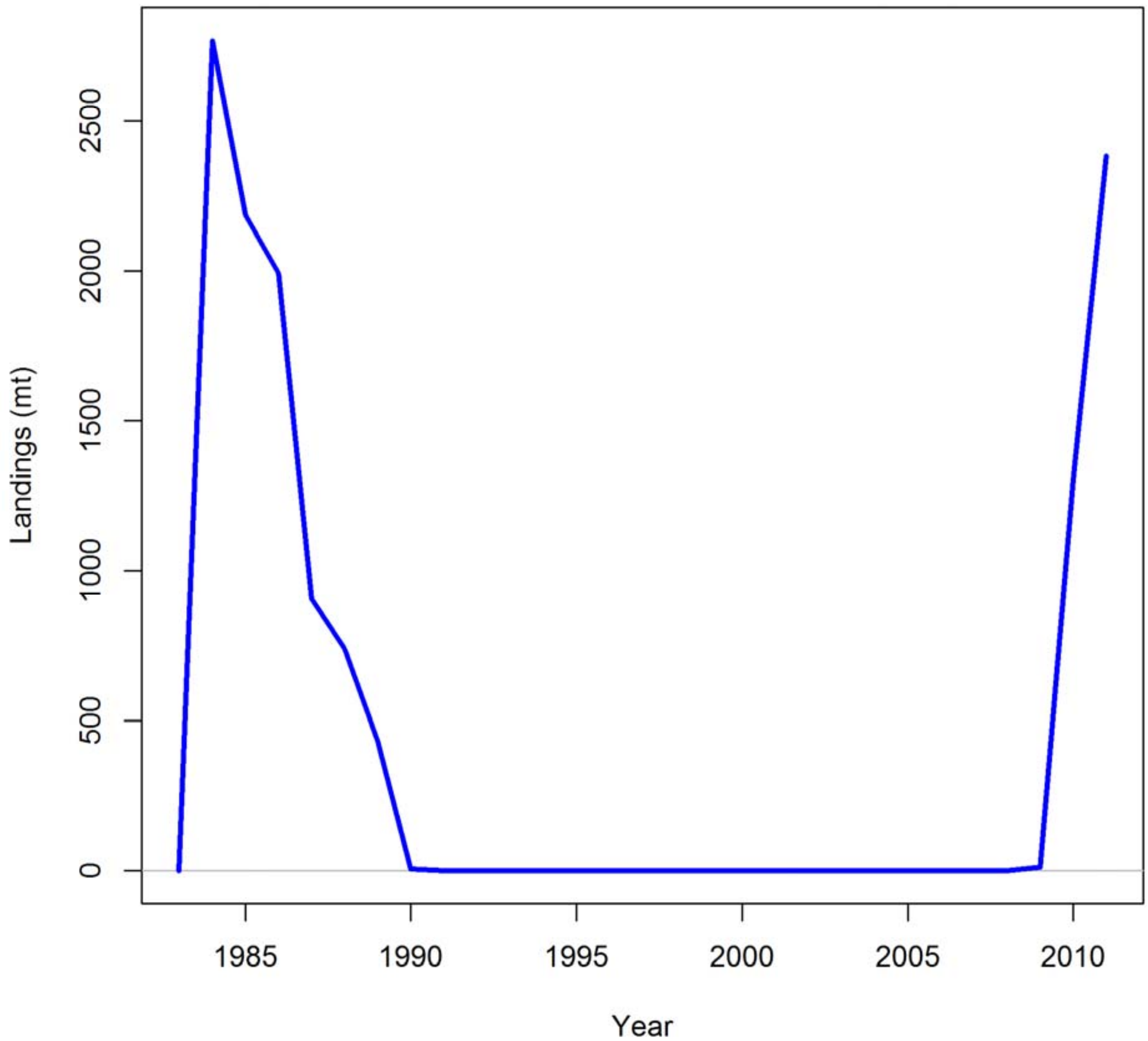




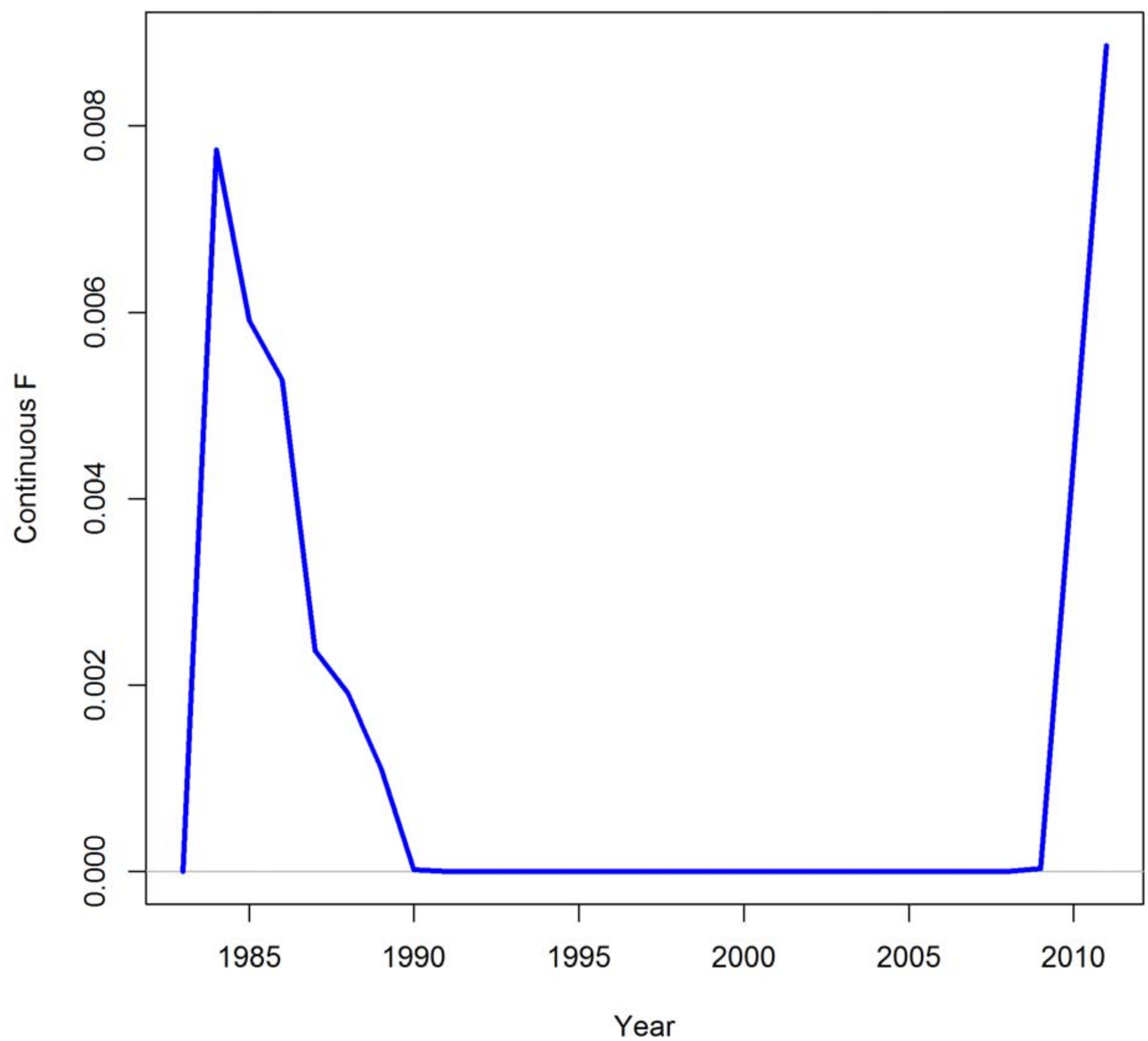
Maturity
0.5
0.6
0.7
0.8
0.9
1.0
0
5
10
15
20
25
30
Age (yr)


Spawning output
1.4
1.2
1.0
0.8
0.6
5
10
15
20
Length (cm)


Ending year expected growth
Length (cm, middle of the year)
0
5
10
15
0
5
10
15
20
25
30
Age (yr)

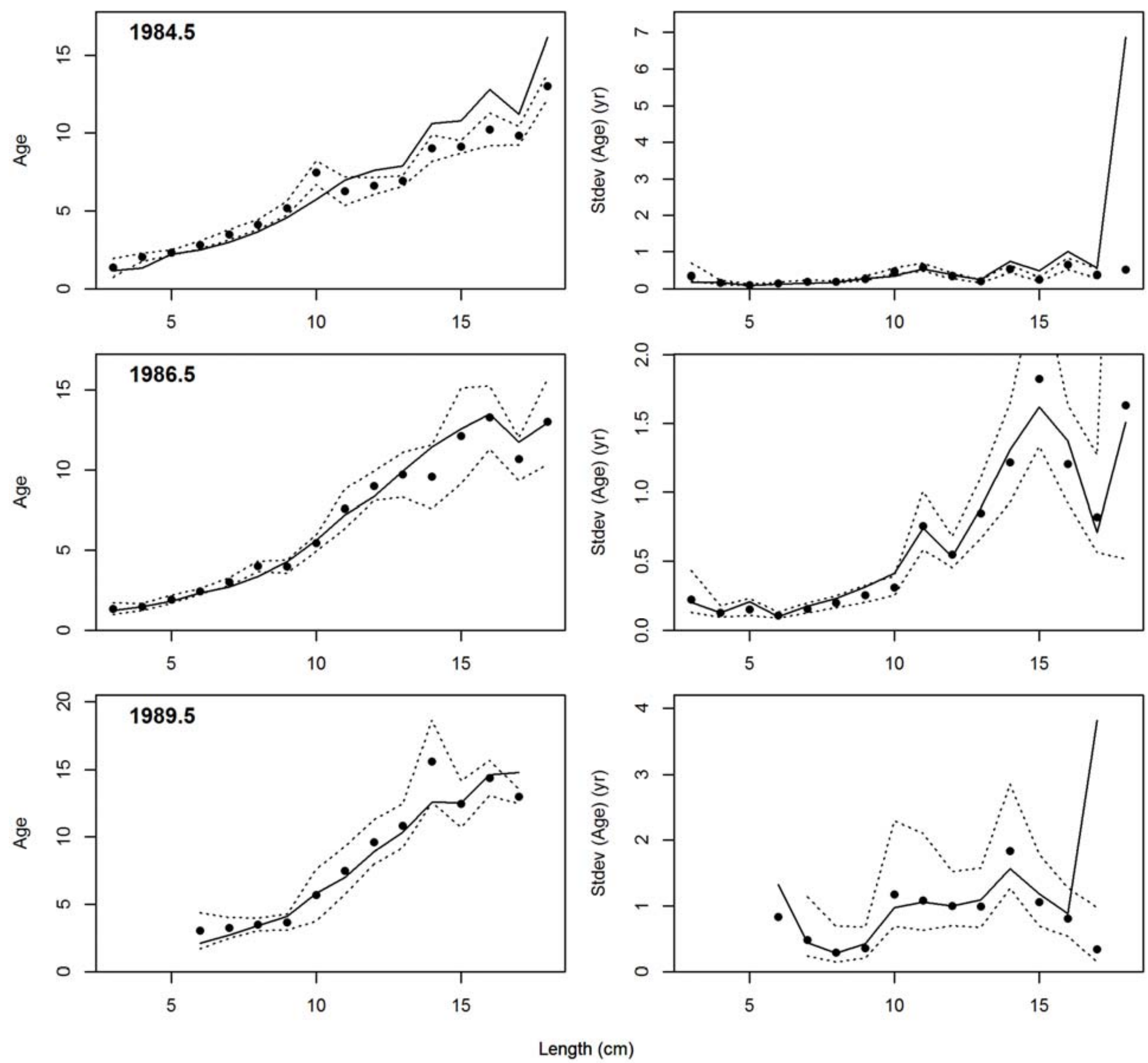


Landings (mt)
0
500
1000
1500
2000
2500
1985
1990
1995
2000
2005
2010
Year

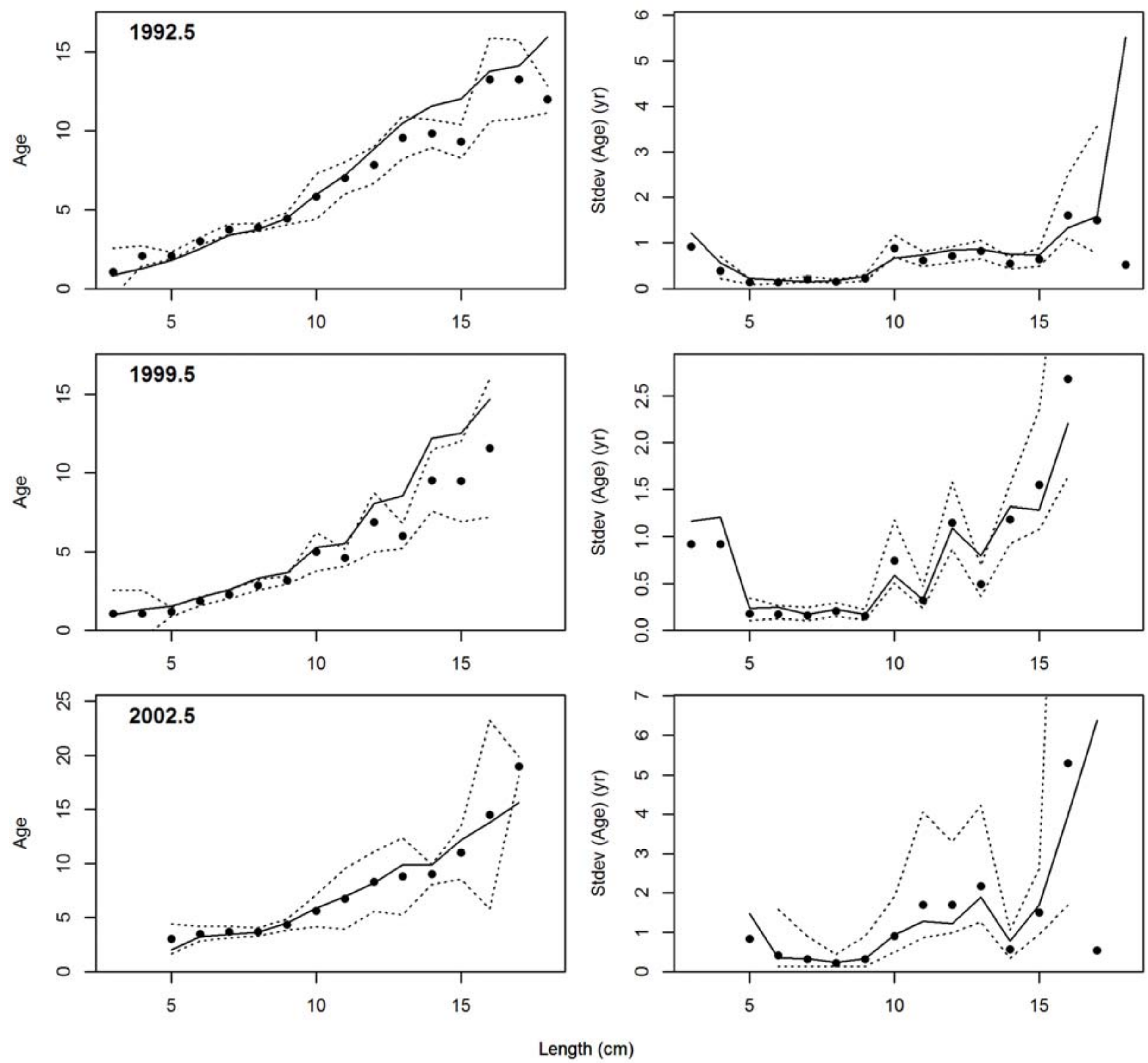


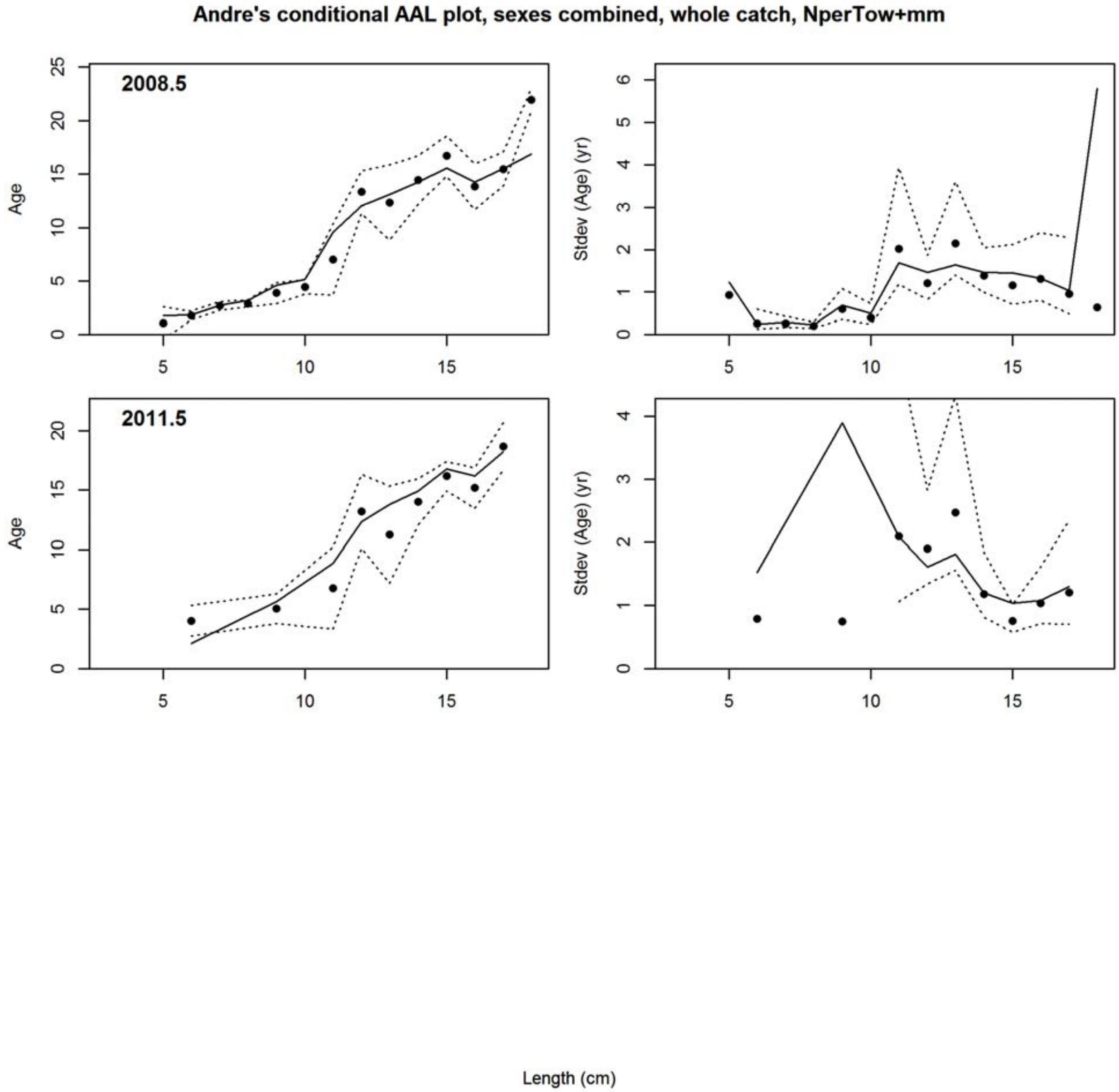
Continuous F
0.000
0.002
0.004
0.006
0.008
1985
1990
1995
2000
2005
2010
Year

Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm

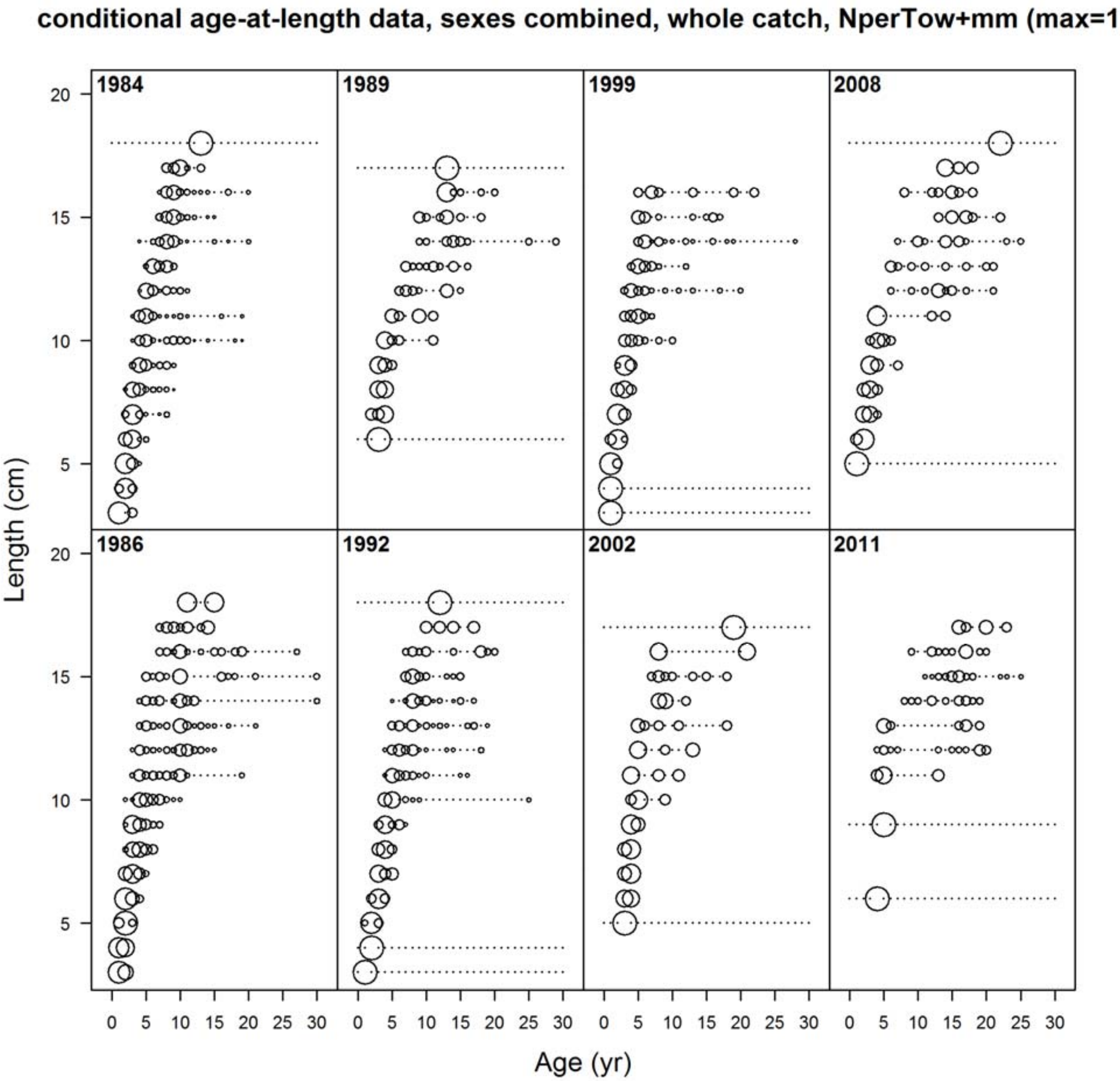


Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm

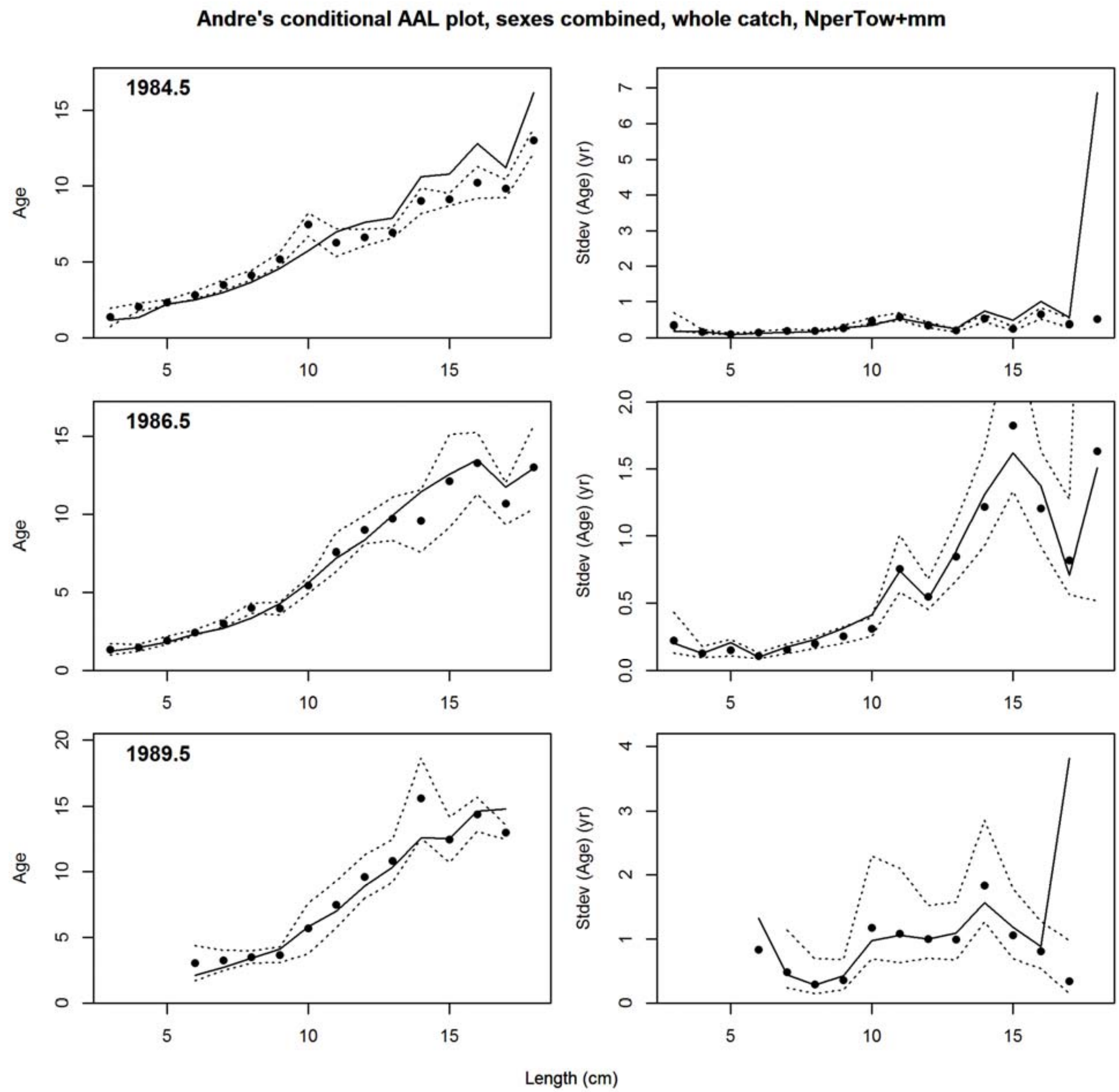




Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm
2008.5
2011.5
Age
Stdev (Age) (yr)
Length (cm)

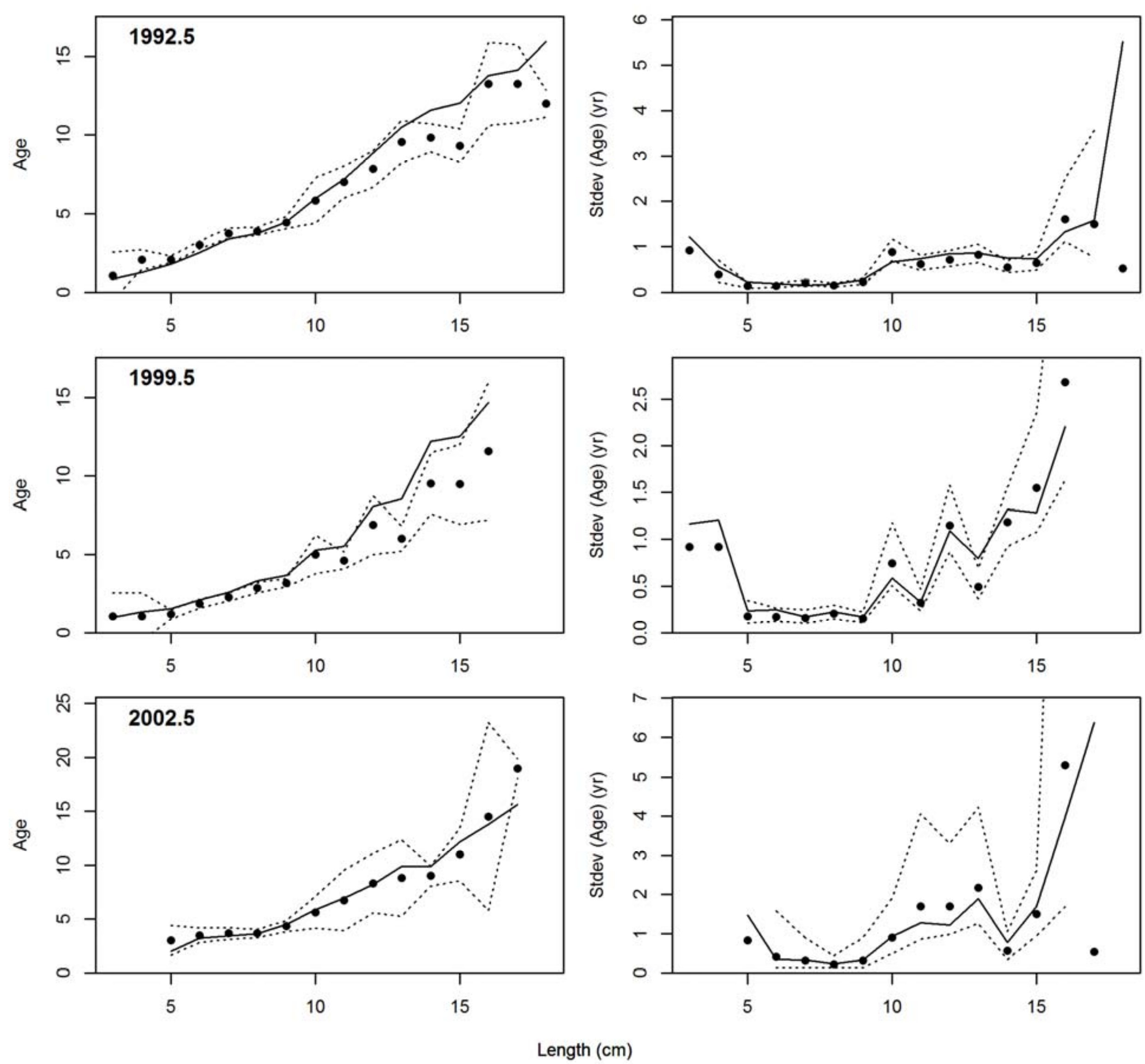


conditional age-at-length data, sexes combined, whole catch, NperTow+mm (max=1
1984
1989
1999
2008
1986
1992
2002
2011
Length (cm)
Age (yr)

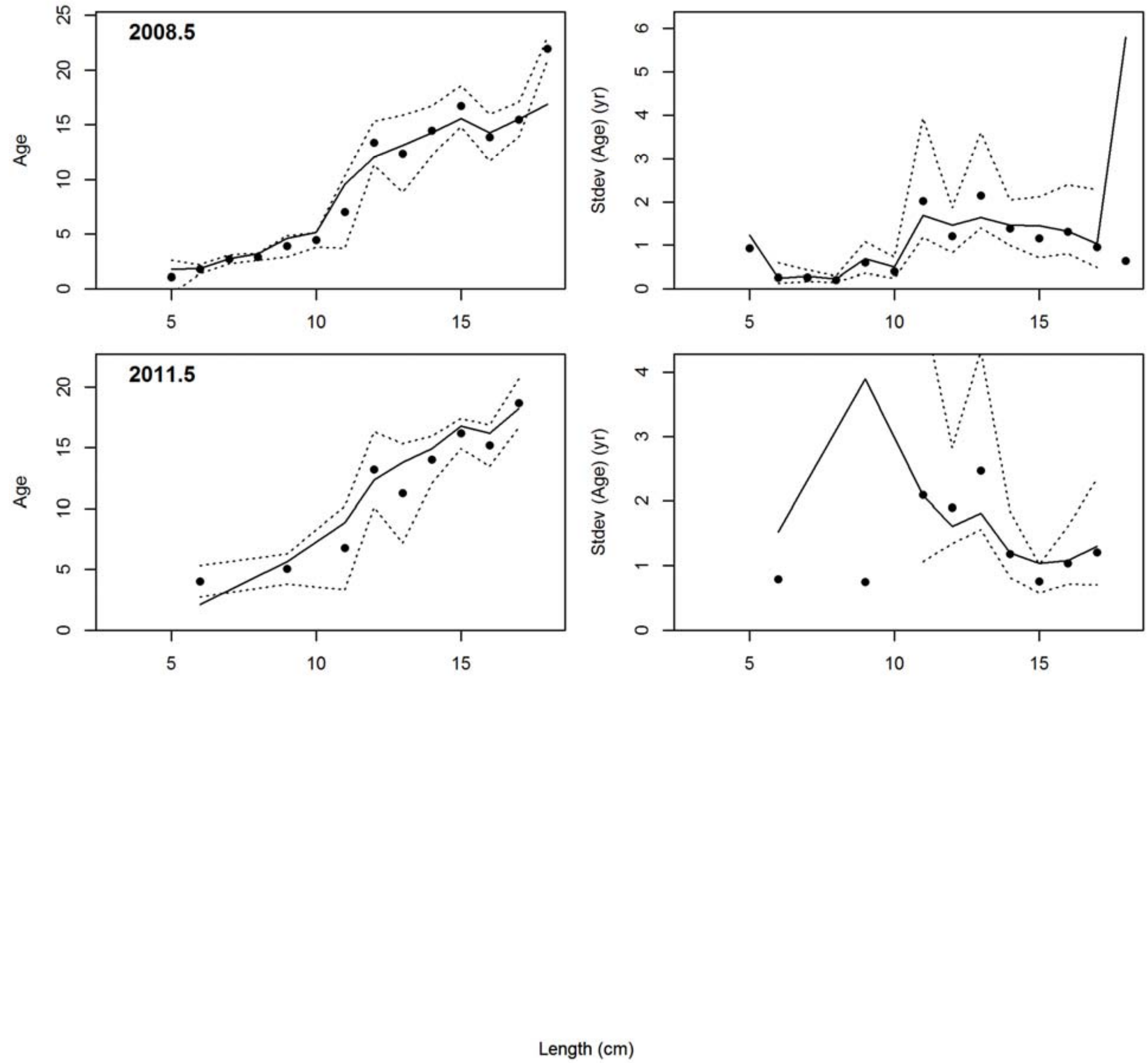


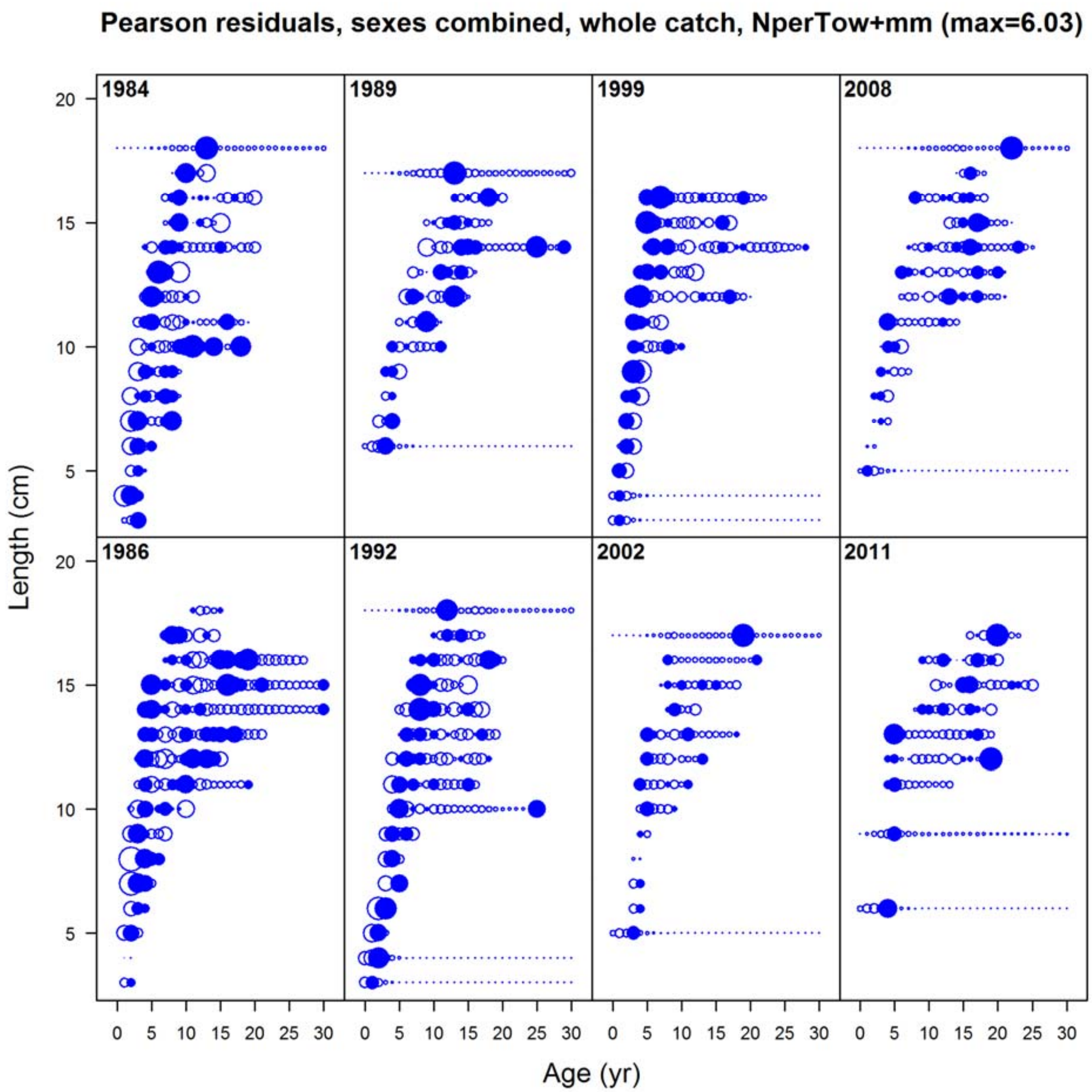
Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm
1984.5
1986.5
1989.5
Age
Stdev (Age) (yr)
Length (cm)

Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm

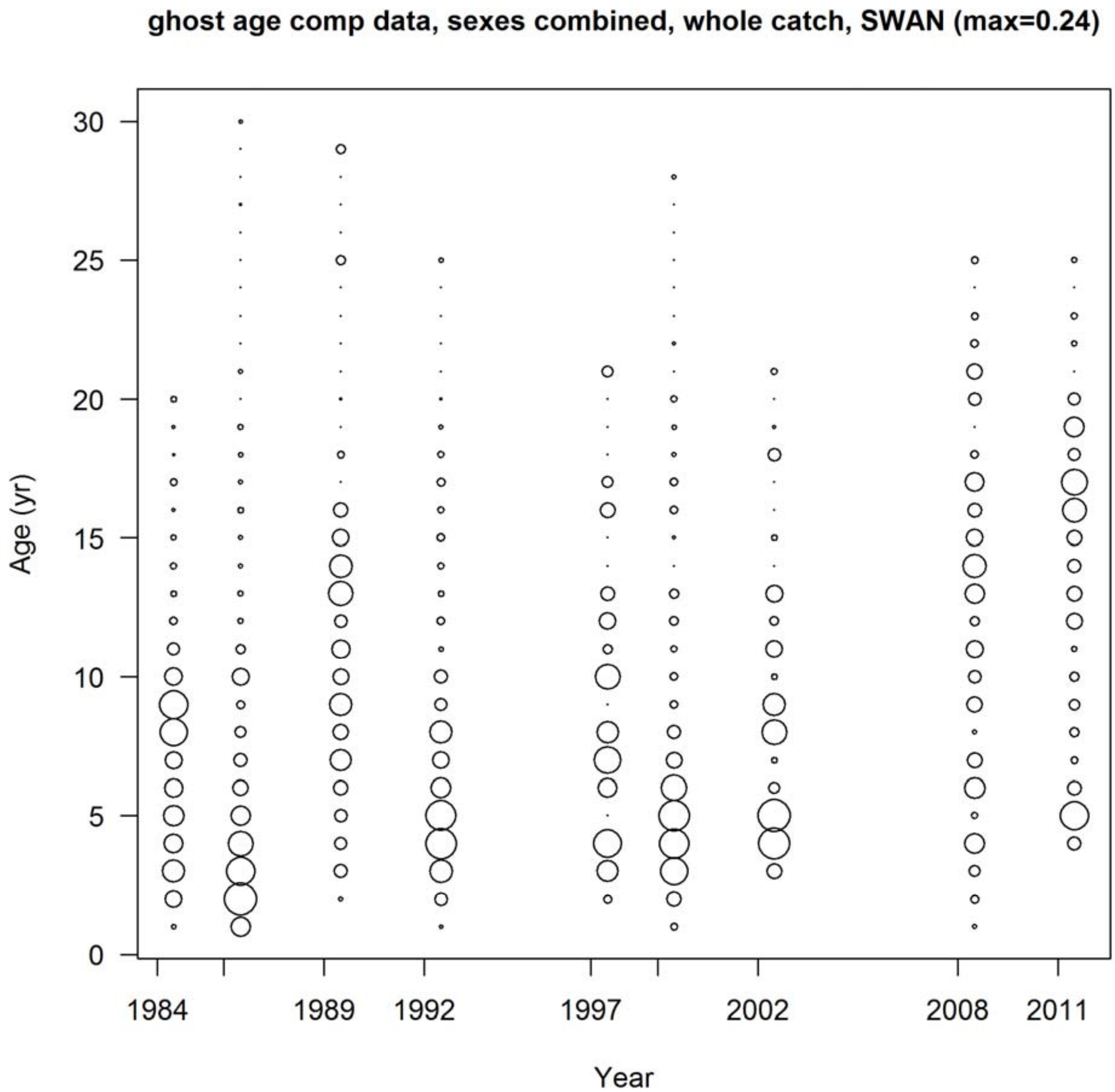


Andre's conditional AAL plot, sexes combined, whole catch, NperTow+mm

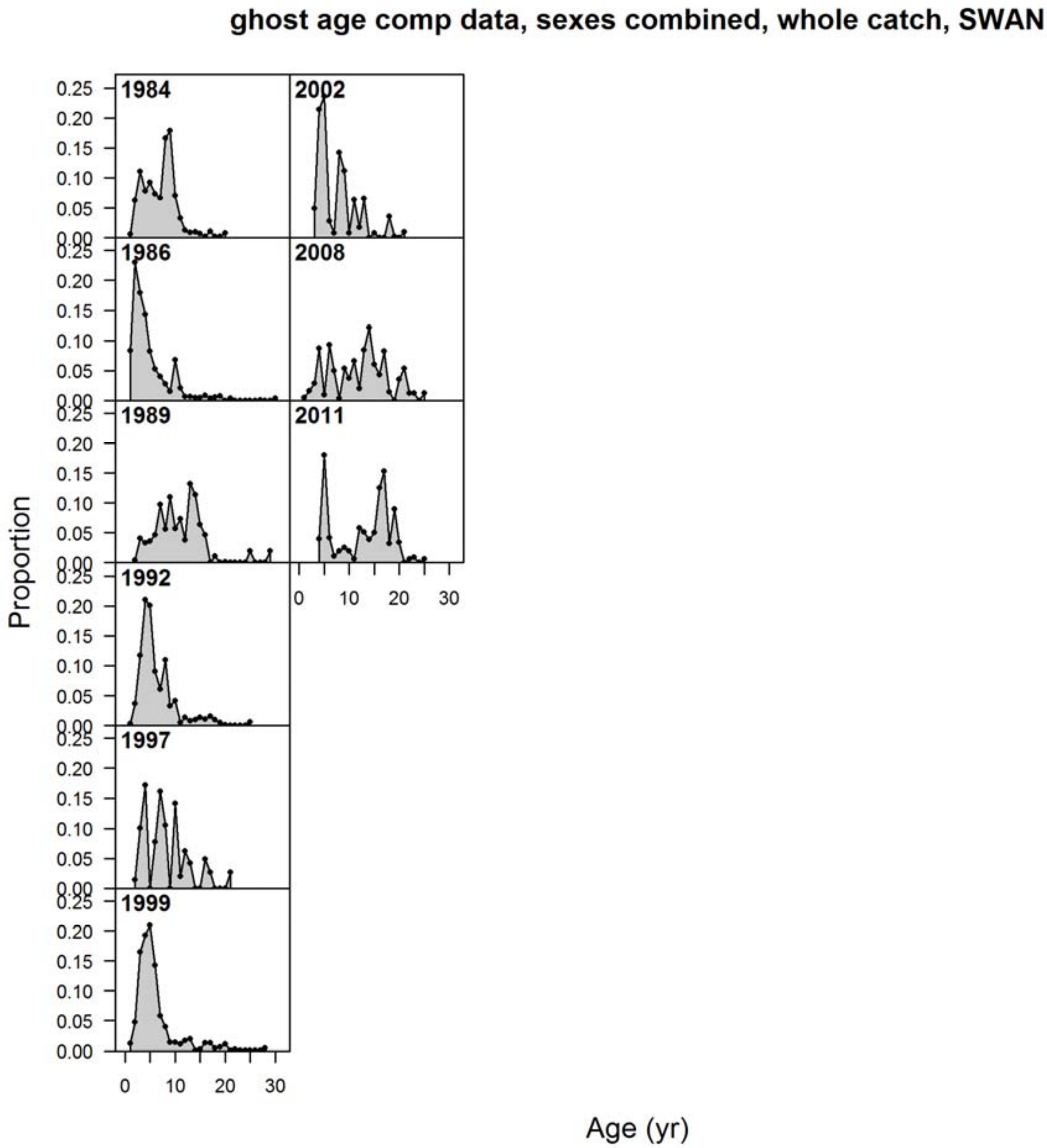




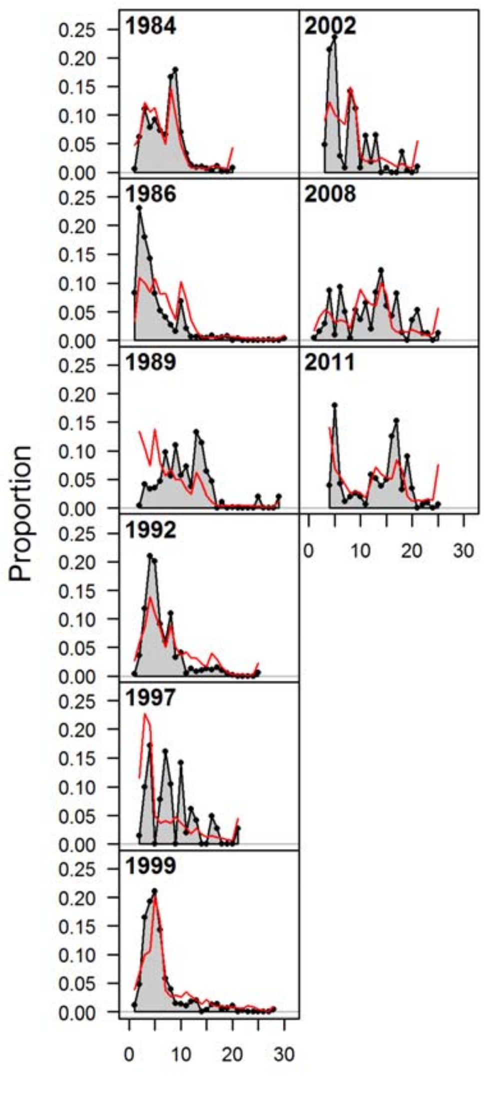
Pearson residuals, sexes combined, whole catch, NperTow+mm (max=6.03)
1984
1989
1999
2008
1986
1992
2002
2011
Length (cm)
Age (yr)



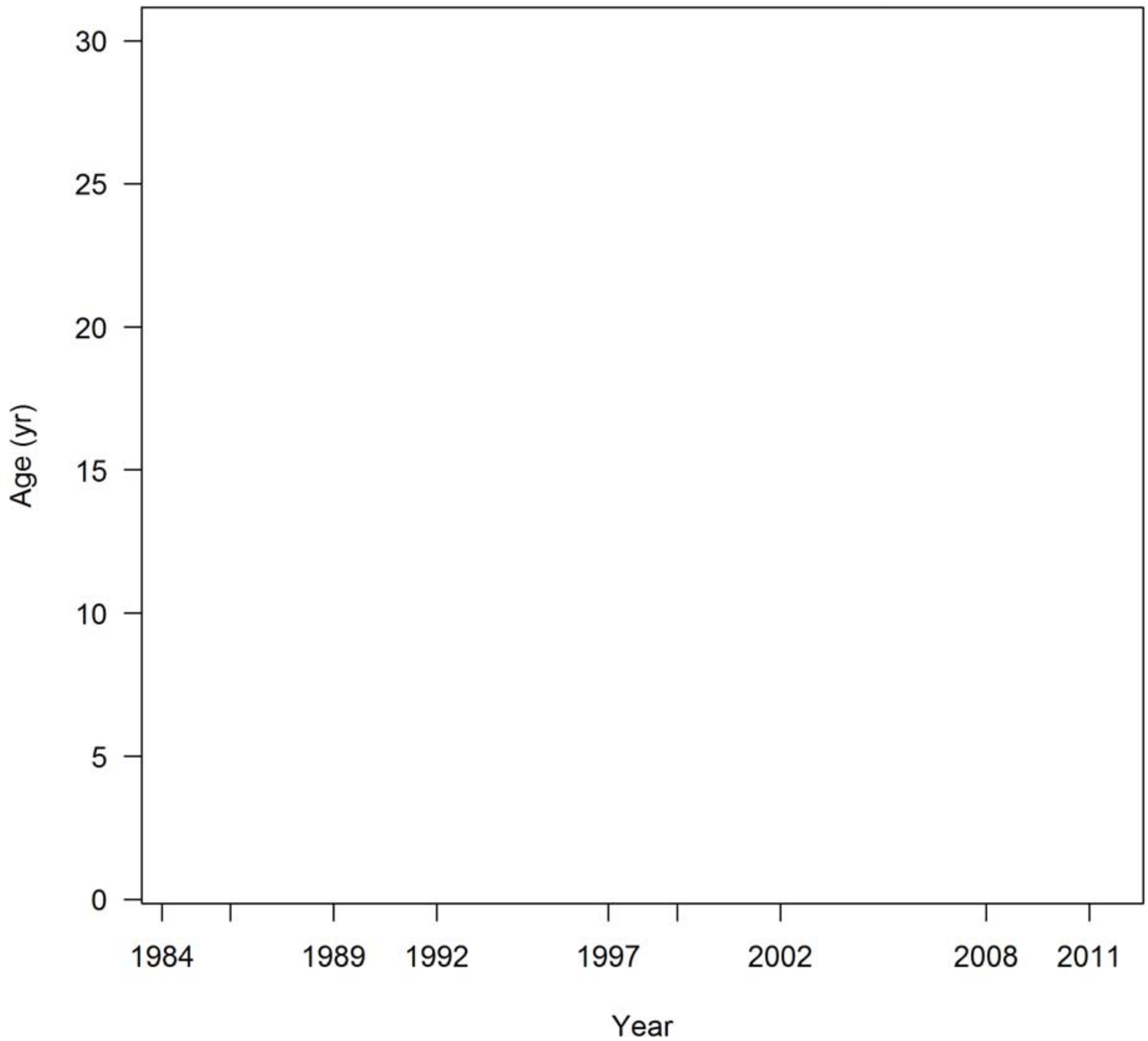
ghost age comp data, sexes combined, whole catch, SWAN (max=0.24)
Age (yr)
30
25
20
15
10
5
0
1984
1989
1992
1997
2002
2008
2011
Year

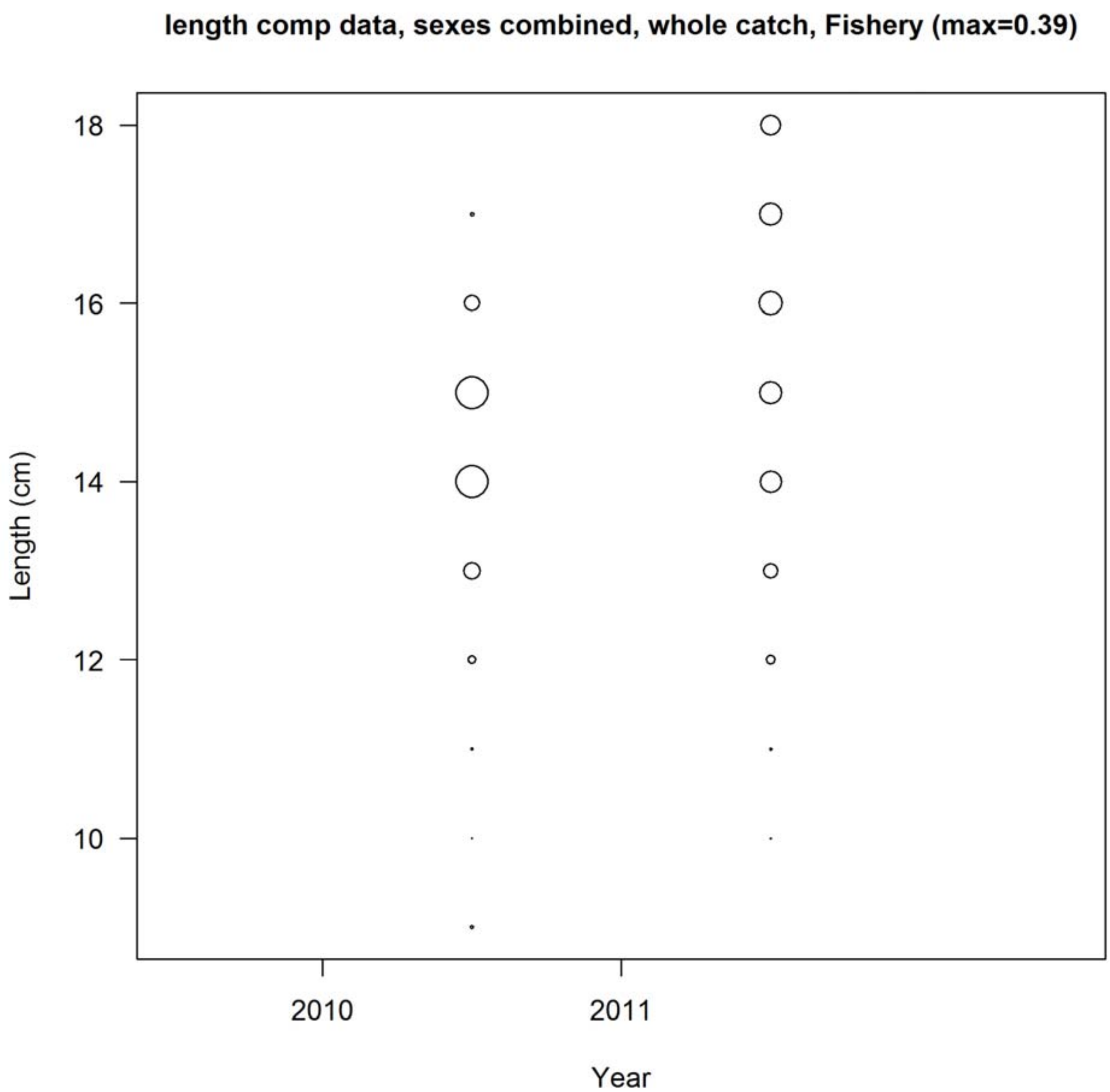

ghost age comp data, sexes combined, whole catch, SWAN
1984
2002
1986
2008
1989
2011
1992
1997
1999
Proportion
Age (yr)
0.00
0.05
0.10
0.15
0.20
0.25
0
10
20
30

ghost age comps, sexes combined, whole catch, SWAN



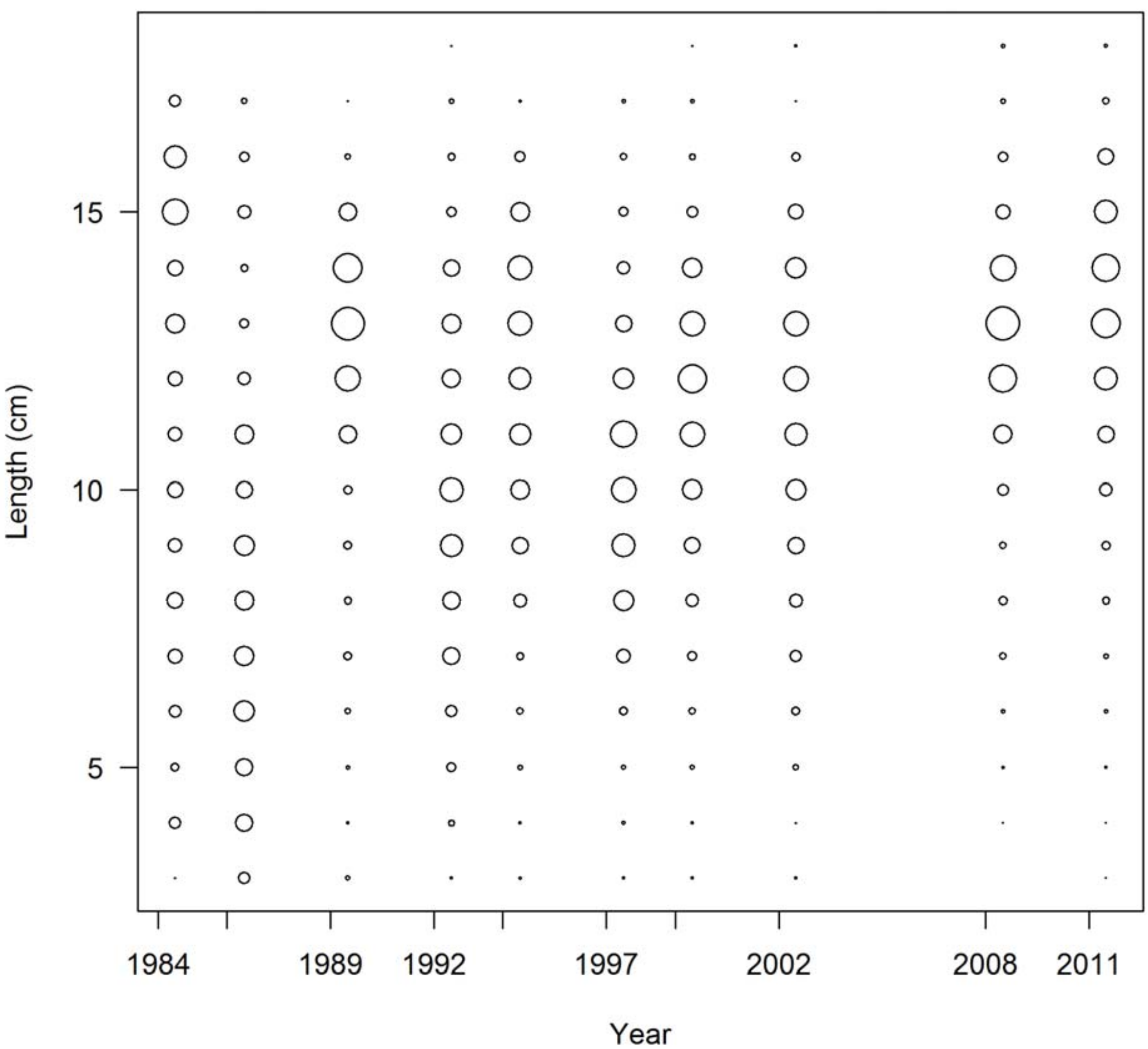
Pearson residuals, sexes combined, whole catch, SWAN (max=NA)

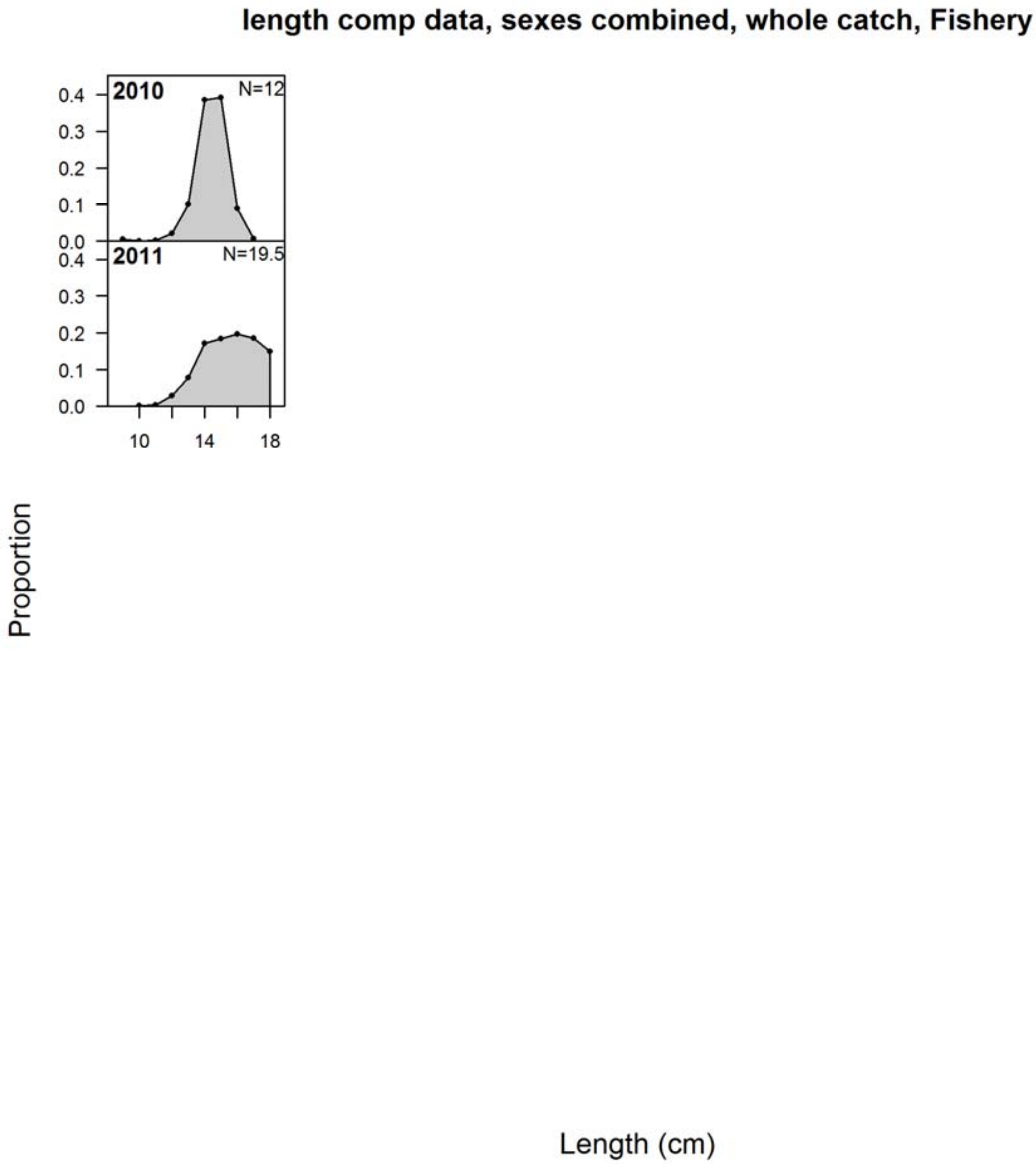




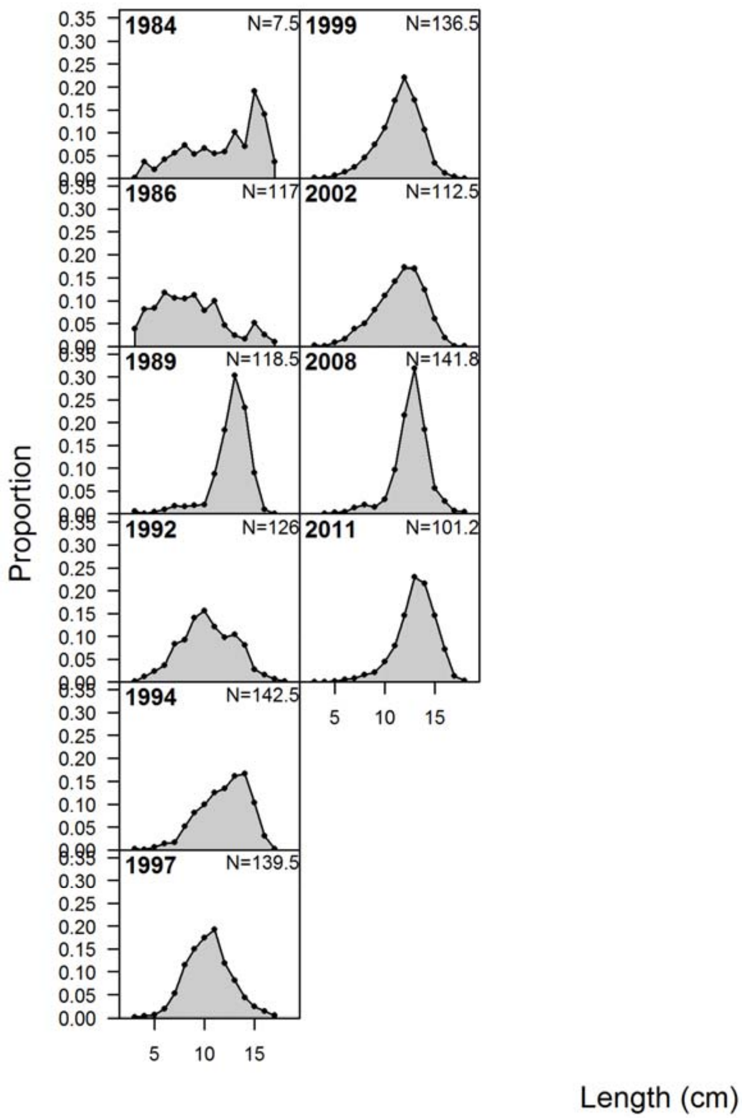
length comp data, sexes combined, whole catch, Fishery (max=0.39)
Length (cm)
18
16
14
12
10
2010
2011
Year

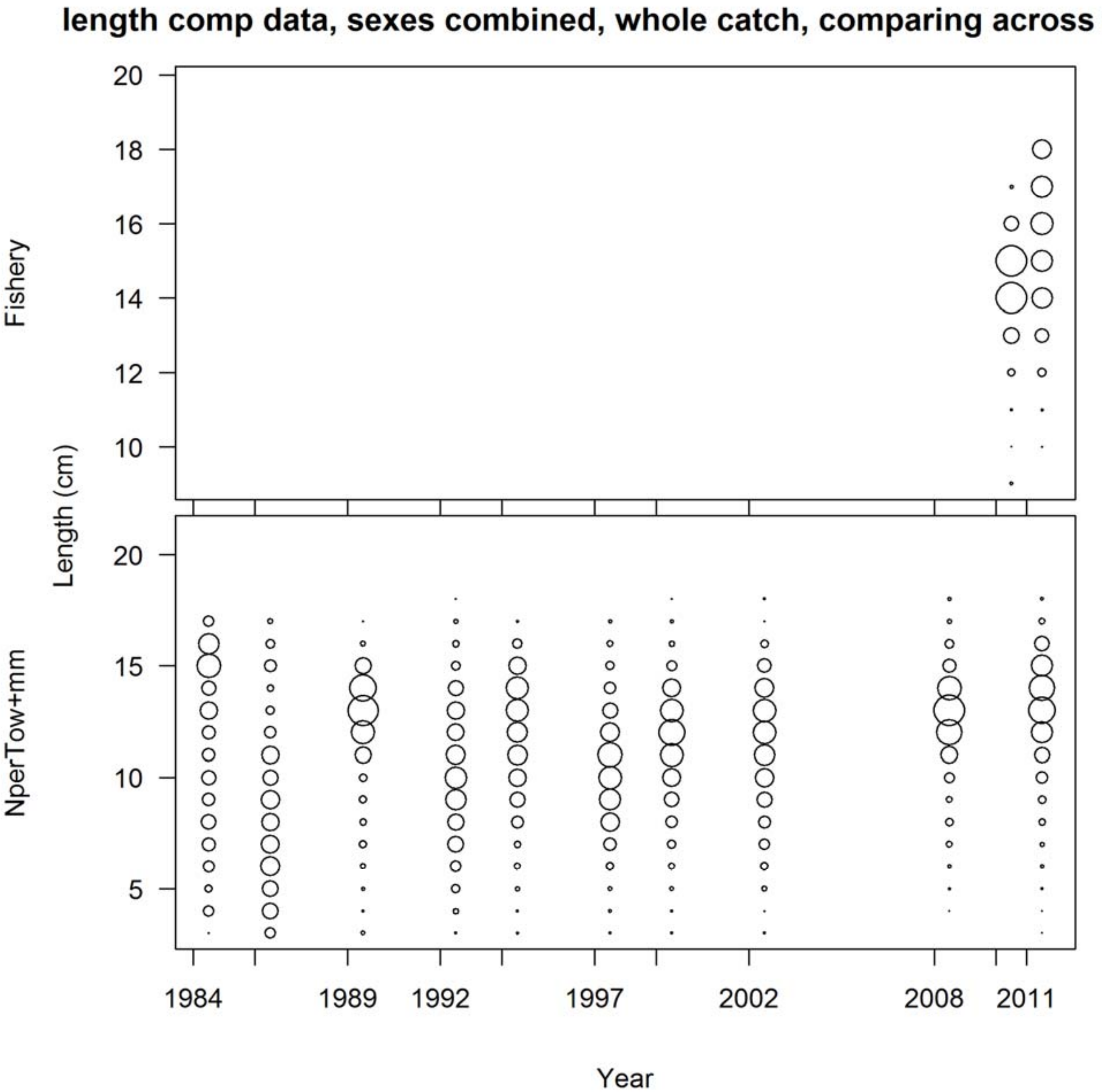
length comp data, sexes combined, whole catch, NperTow+mm (max=0.32)




length comp data, sexes combined, whole catch, Fishery
2010
N=12
2011
N=19.5
0.4
0.3
0.2
0.1
0.0
10
14
18
Proportion
Length (cm)

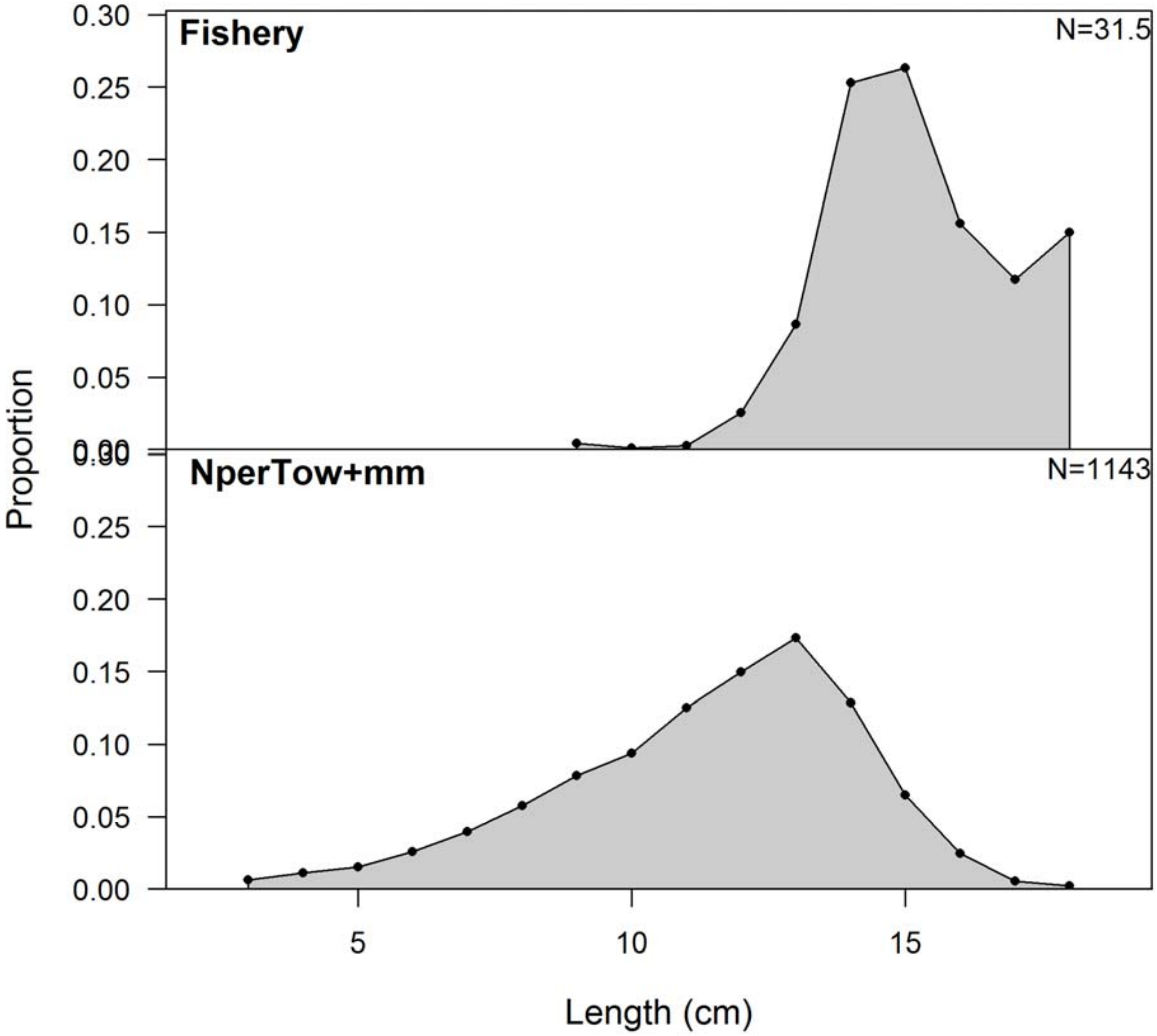
length comp data, sexes combined, whole catch, NperTow+mm

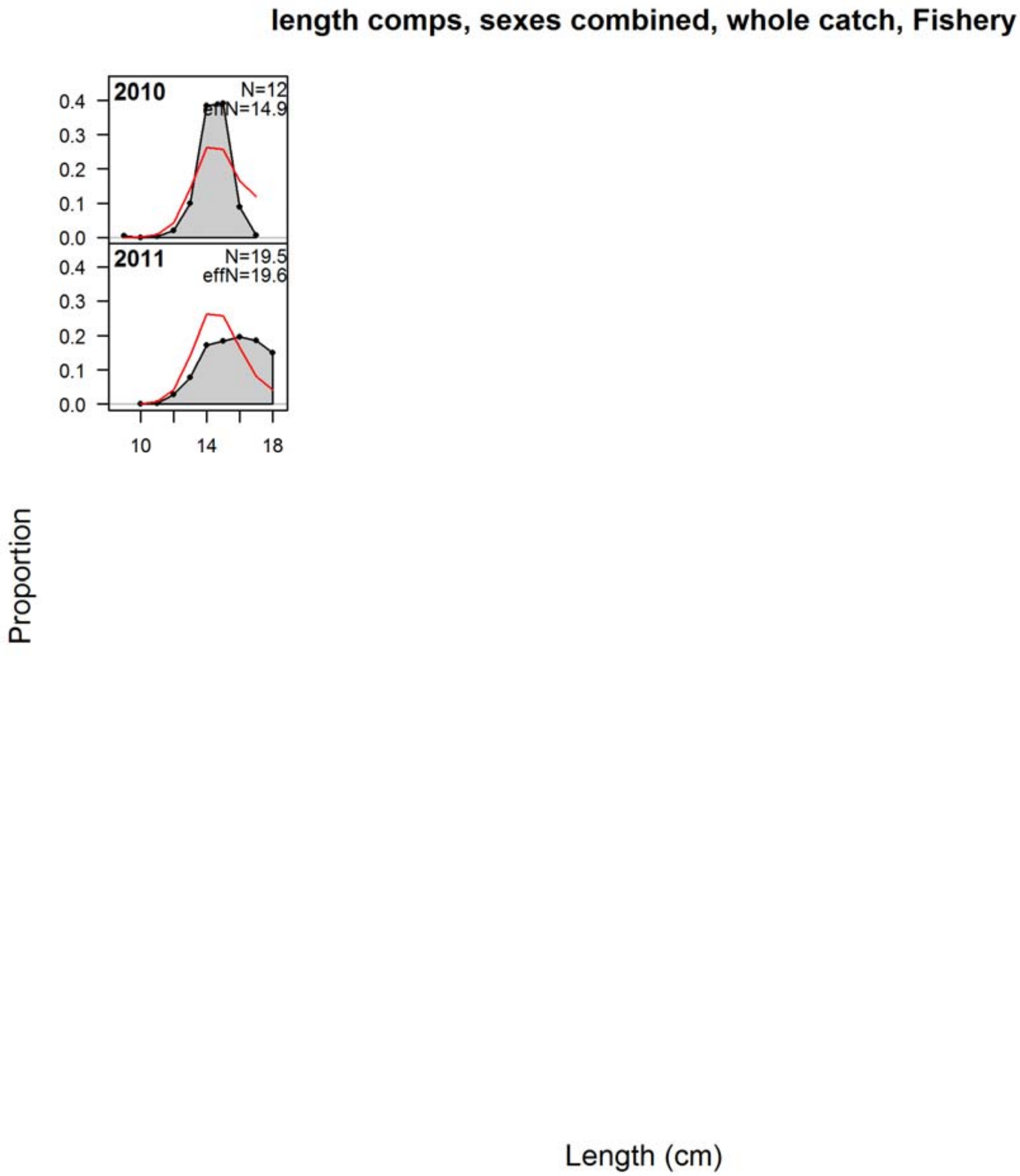




length comp data, sexes combined, whole catch, comparing across t
Fishery
NperTow+mm
Length (cm)
20
18
16
14
12
10
20
15
10
5
1984
1989
1992
1997
2002
2008
2011
Year

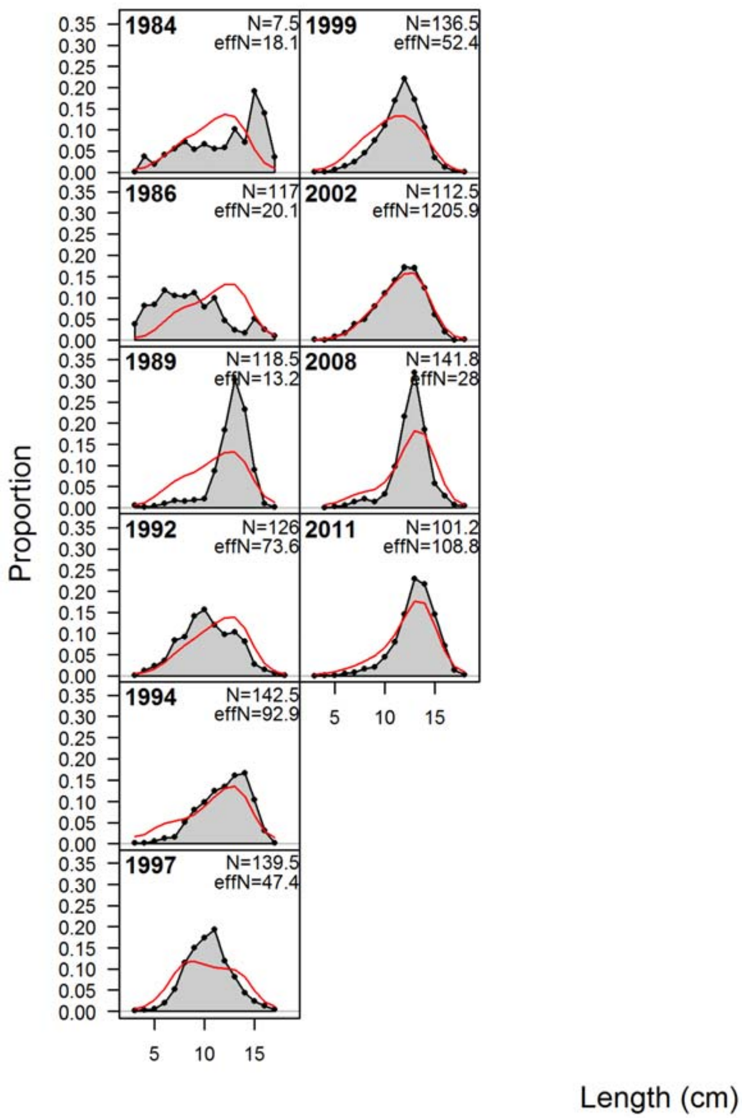
engths comp data, sexes combined, whole catch, aggregated across time b

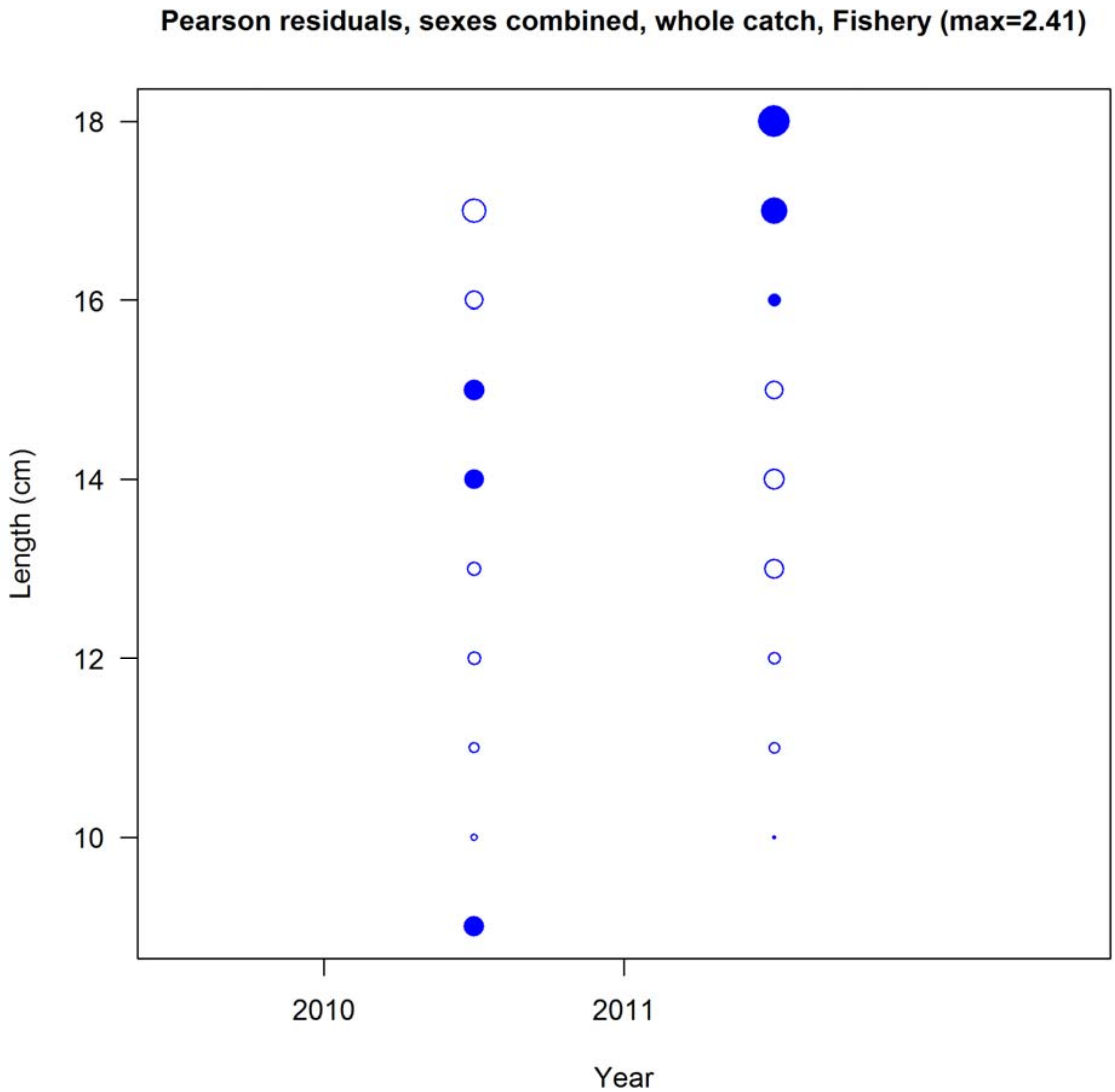


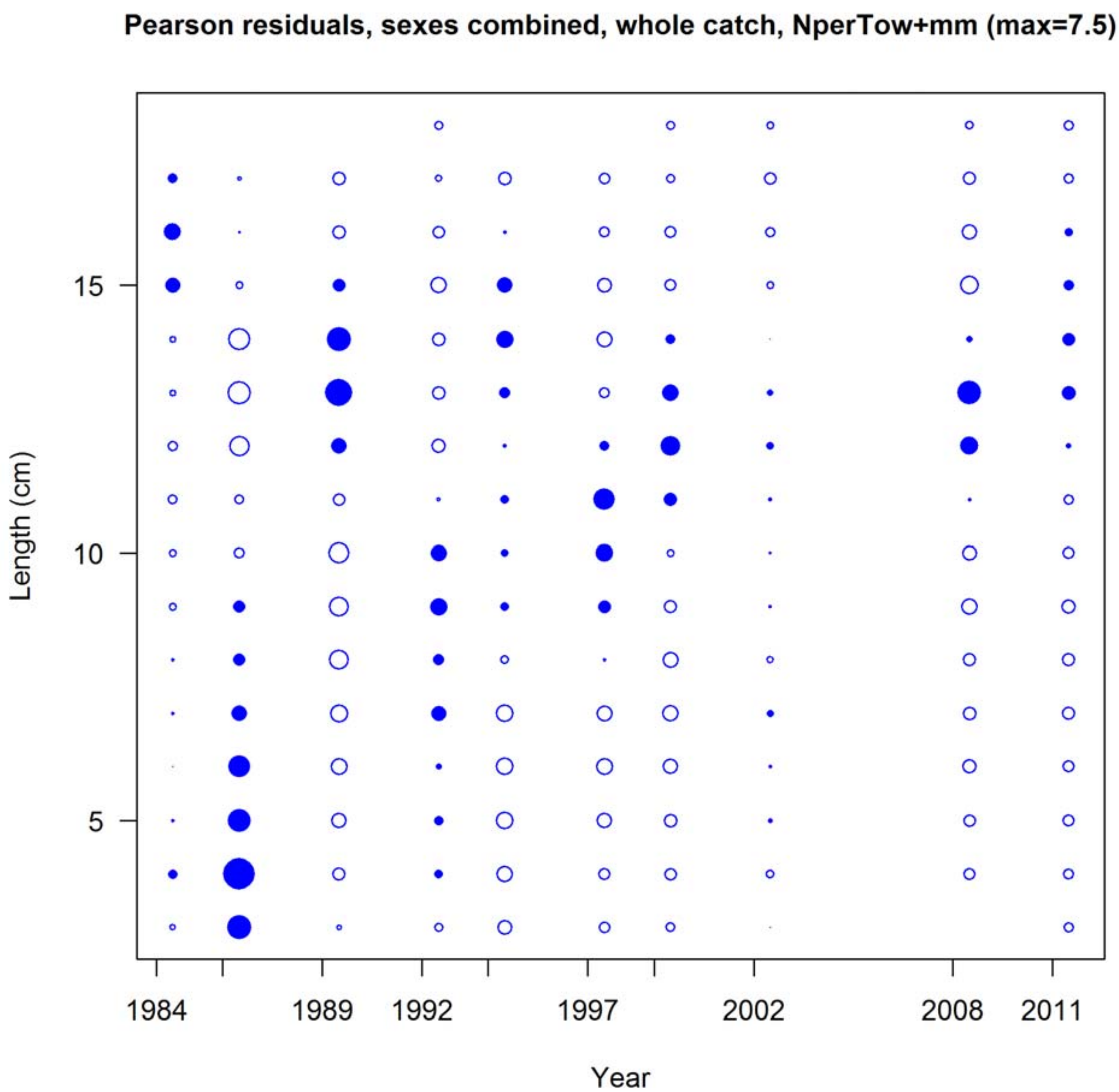


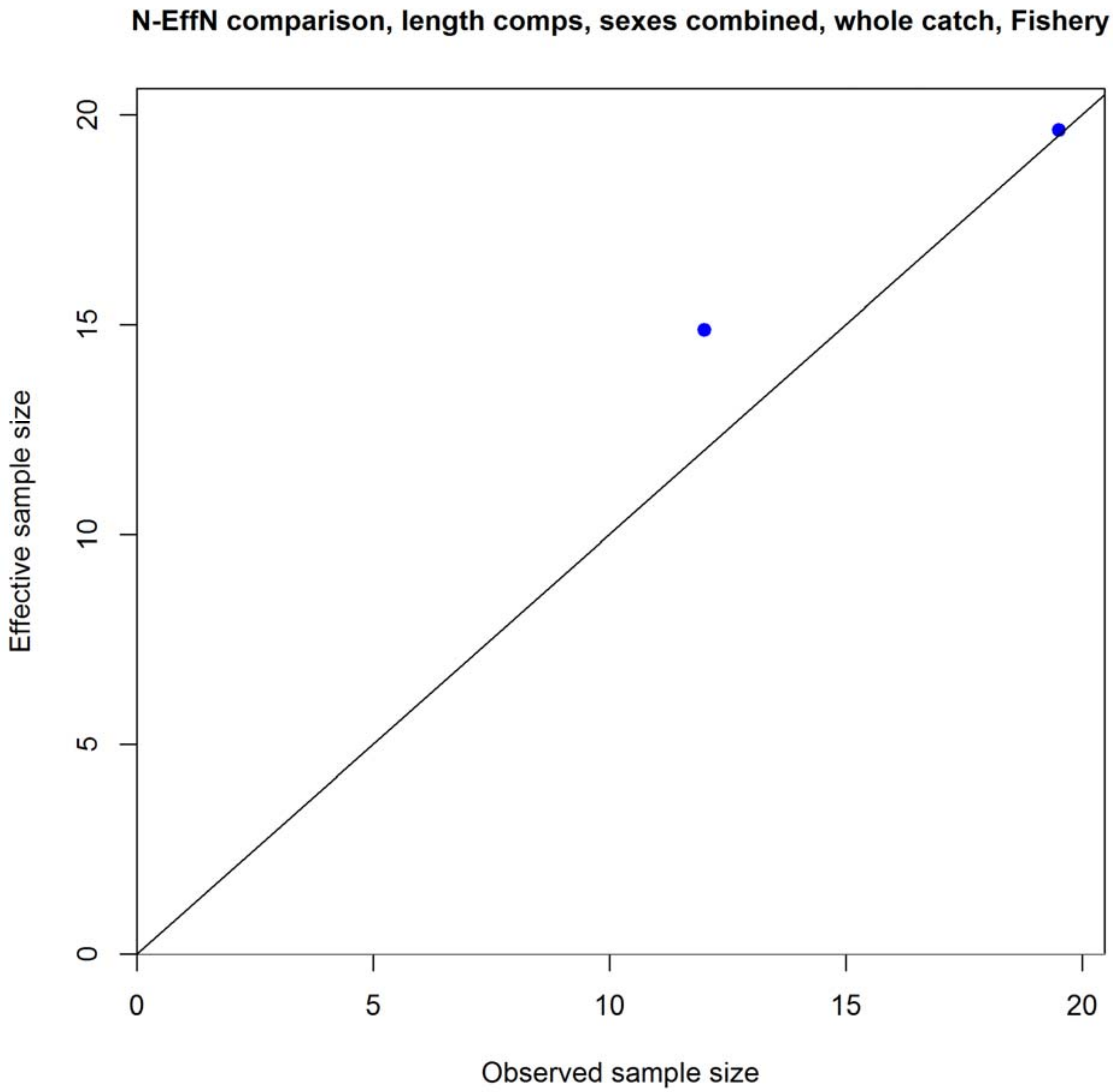
length comps, sexes combined, whole catch, Fishery
2010
N=12
effN=14.9
2011
N=19.5
effN=19.6
0.0
0.1
0.2
0.3
0.4
10
14
18
Proportion
Length (cm)

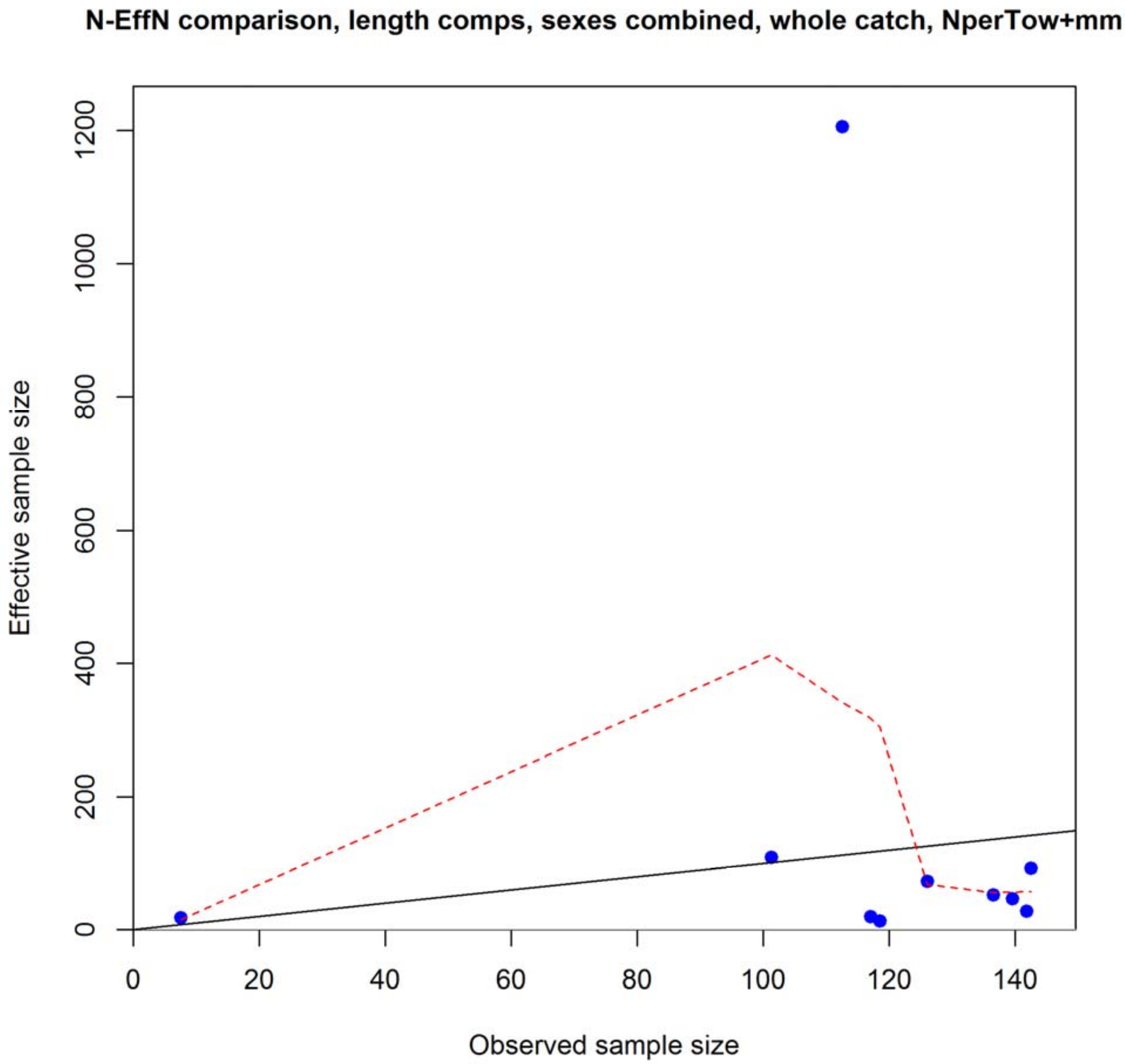
length comps, sexes combined, whole catch, NperTow+mm

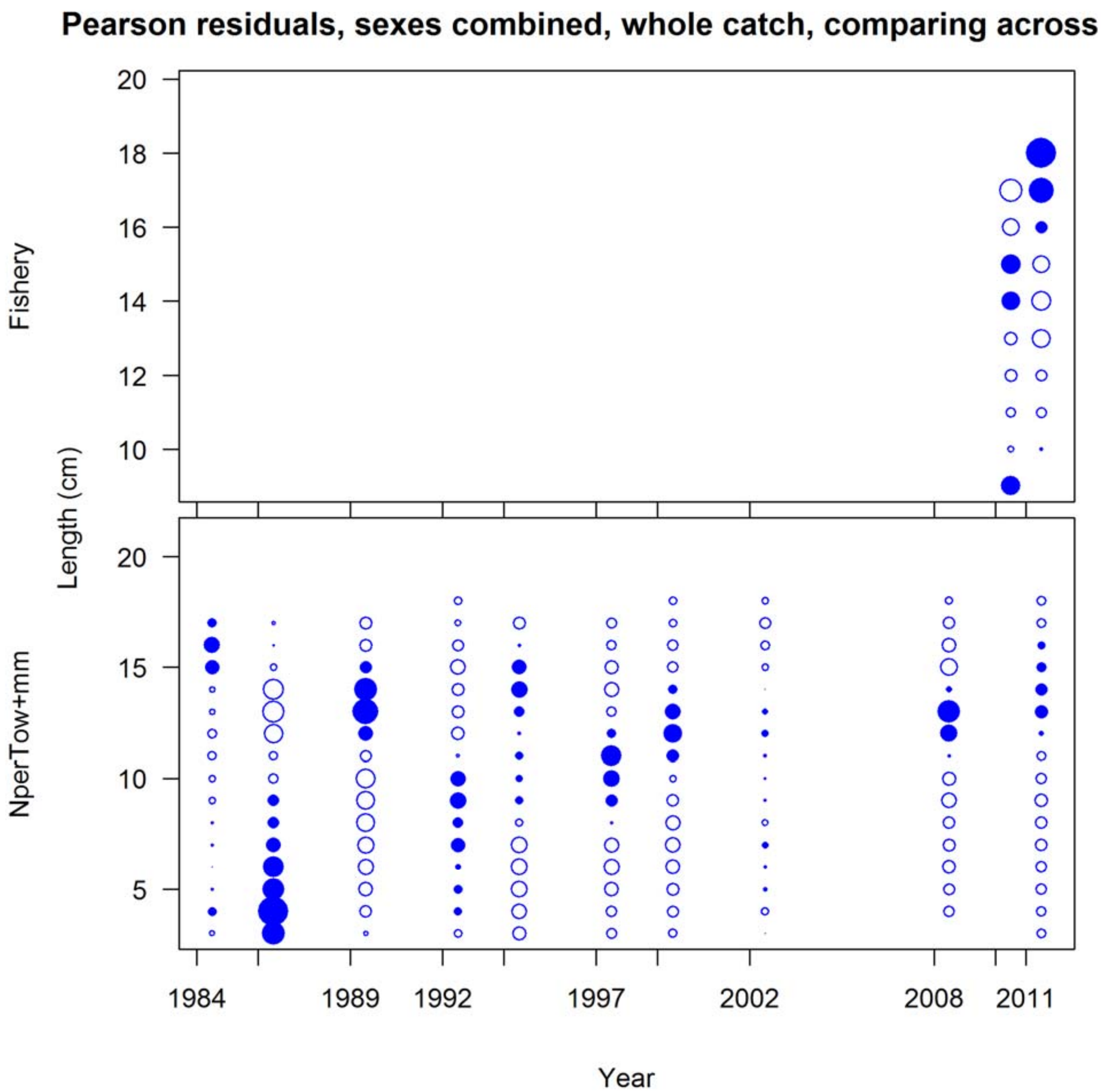



Pearson residuals, sexes combined, whole catch, Fishery (max=2.41)
Length (cm)
18
16
14
12
10
2010
2011
Year


Pearson residuals, sexes combined, whole catch, NperTow+mm (max=7.5)
Length (cm)
15
10
5
1984
1989
1992
1997
2002
2008
2011
Year

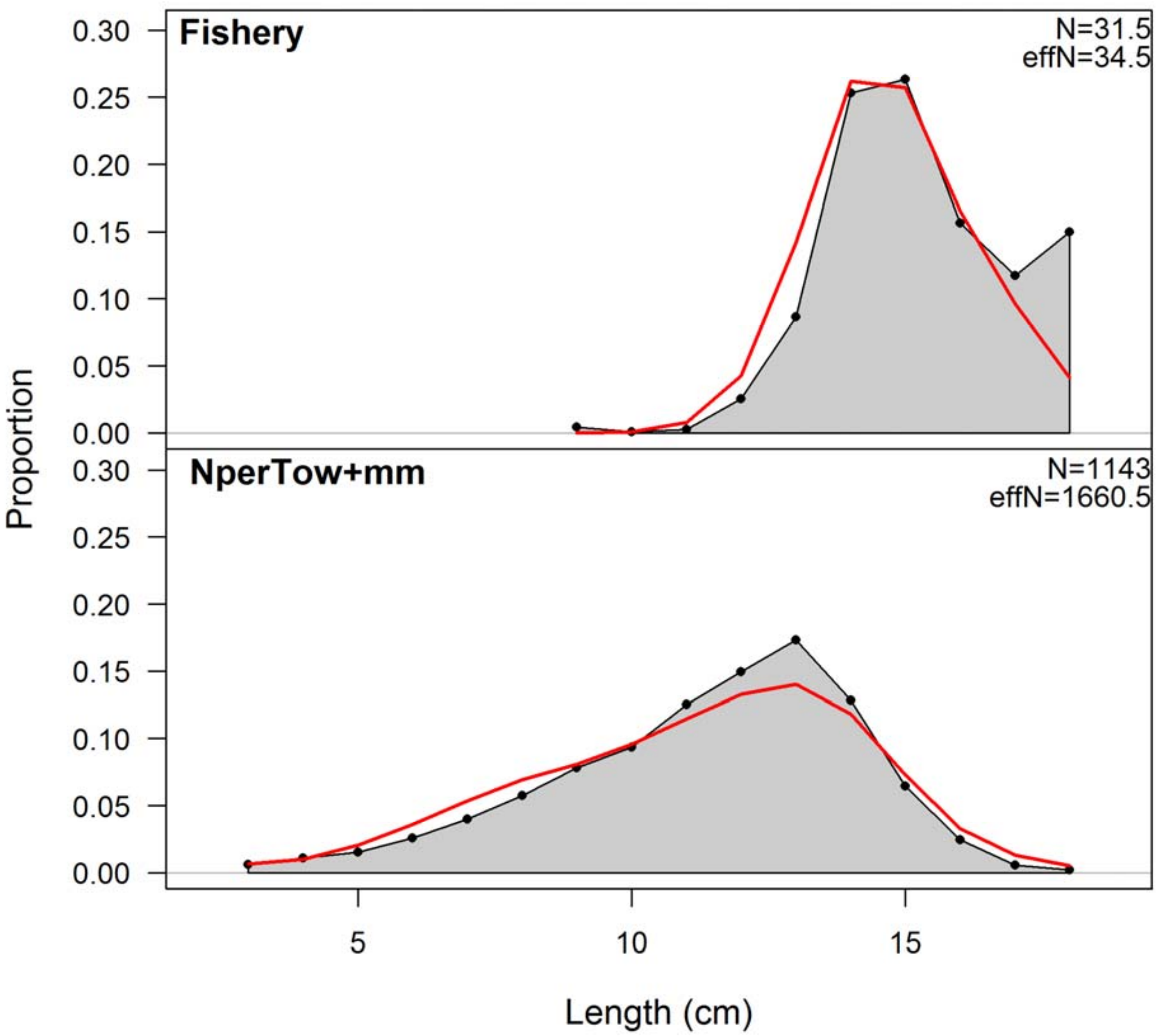

N-EffN comparison, length comps, sexes combined, whole catch, Fishery
Effective sample size
Observed sample size
0
5
10
15
20
0
5
10
15
20

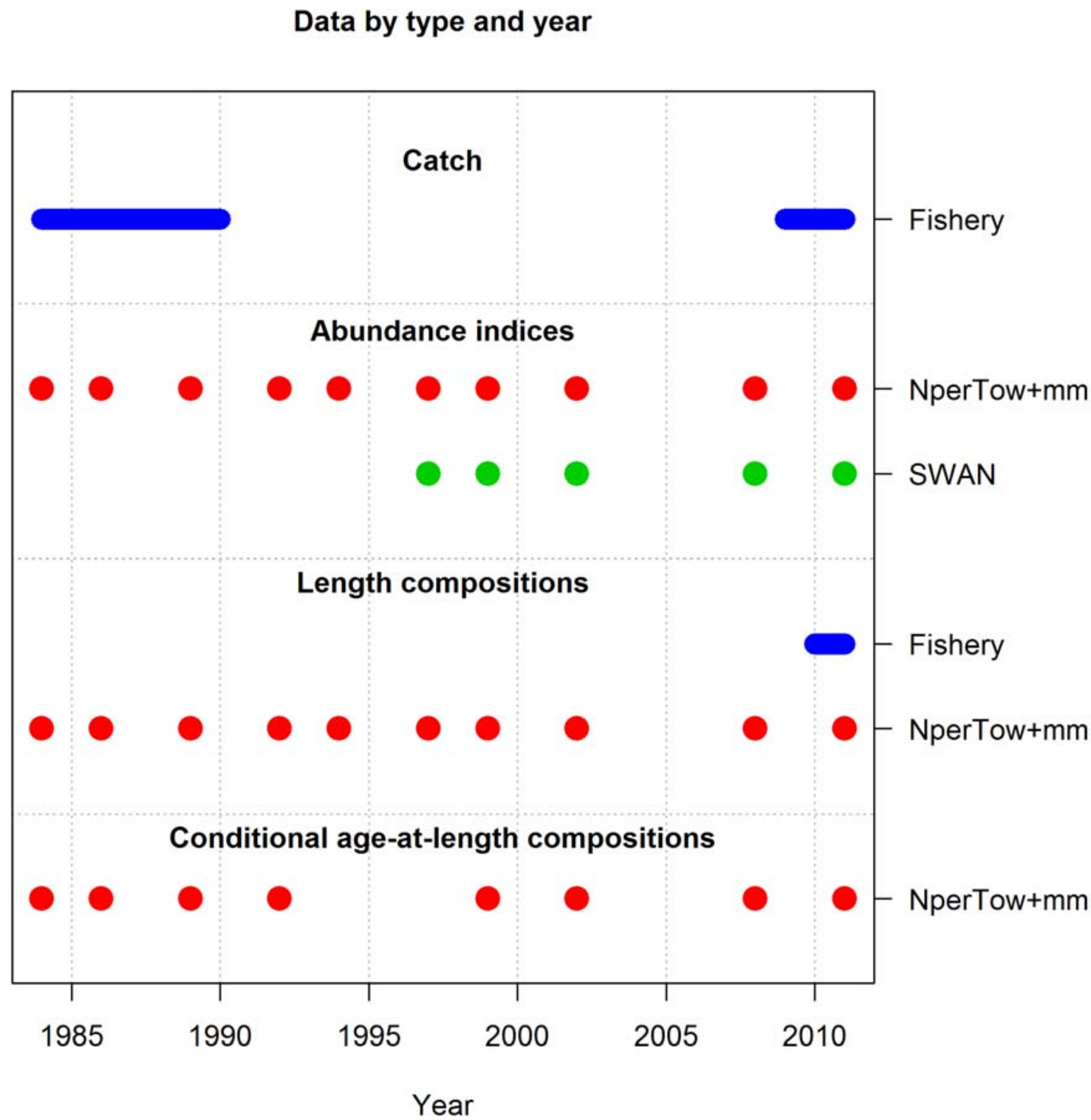

N-EffN comparison, length comps, sexes combined, whole catch, NperTow+mm
Effective sample size
Observed sample size
0
200
400
600
800
1000
1200
0
20
40
60
80
100
120
140



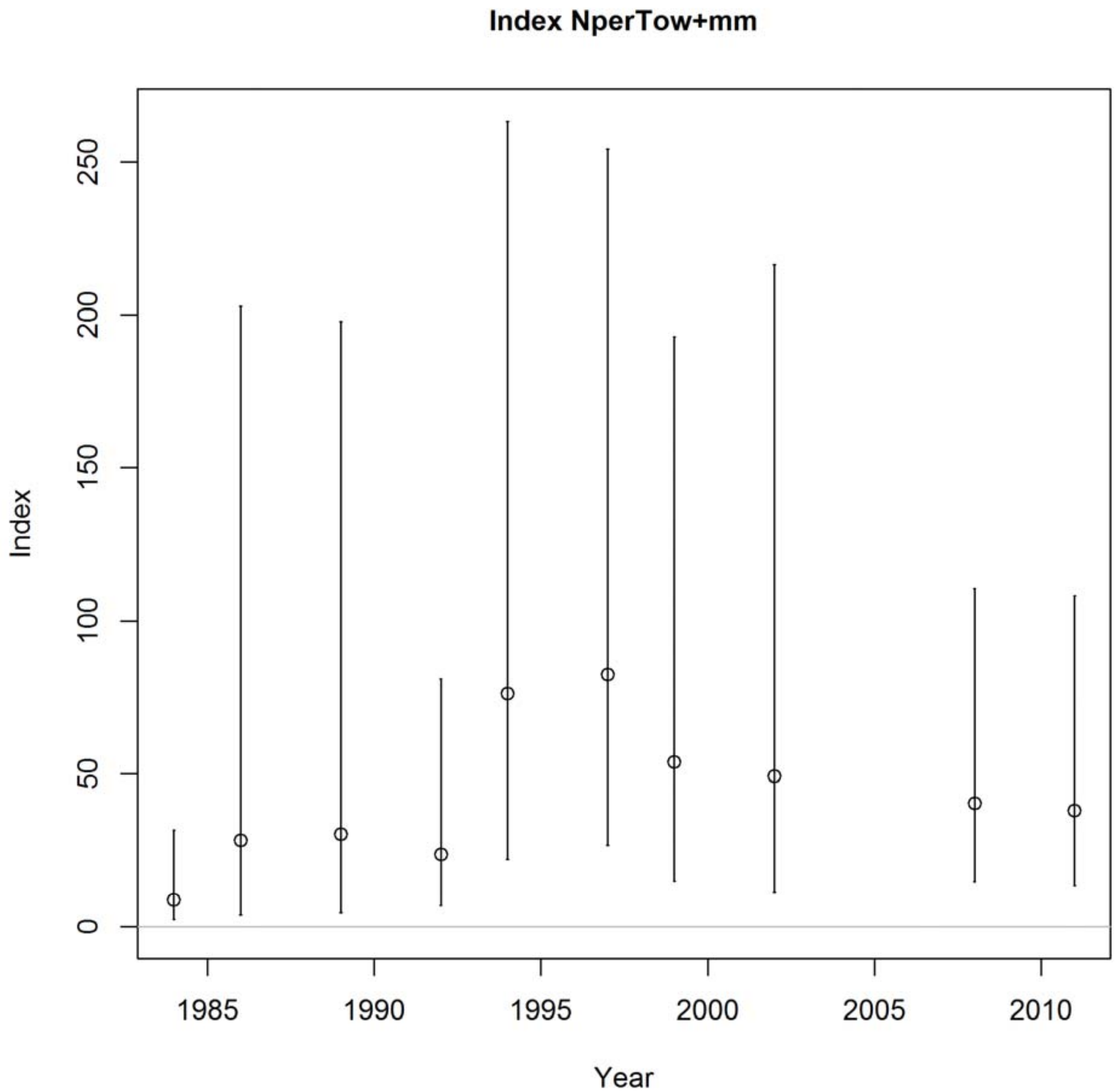
Pearson residuals, sexes combined, whole catch, comparing across
Fishery
NperTow+mm
Length (cm)
20
18
16
14
12
10
20
15
10
5
1984
1989
1992
1997
2002
2008
2011
Year

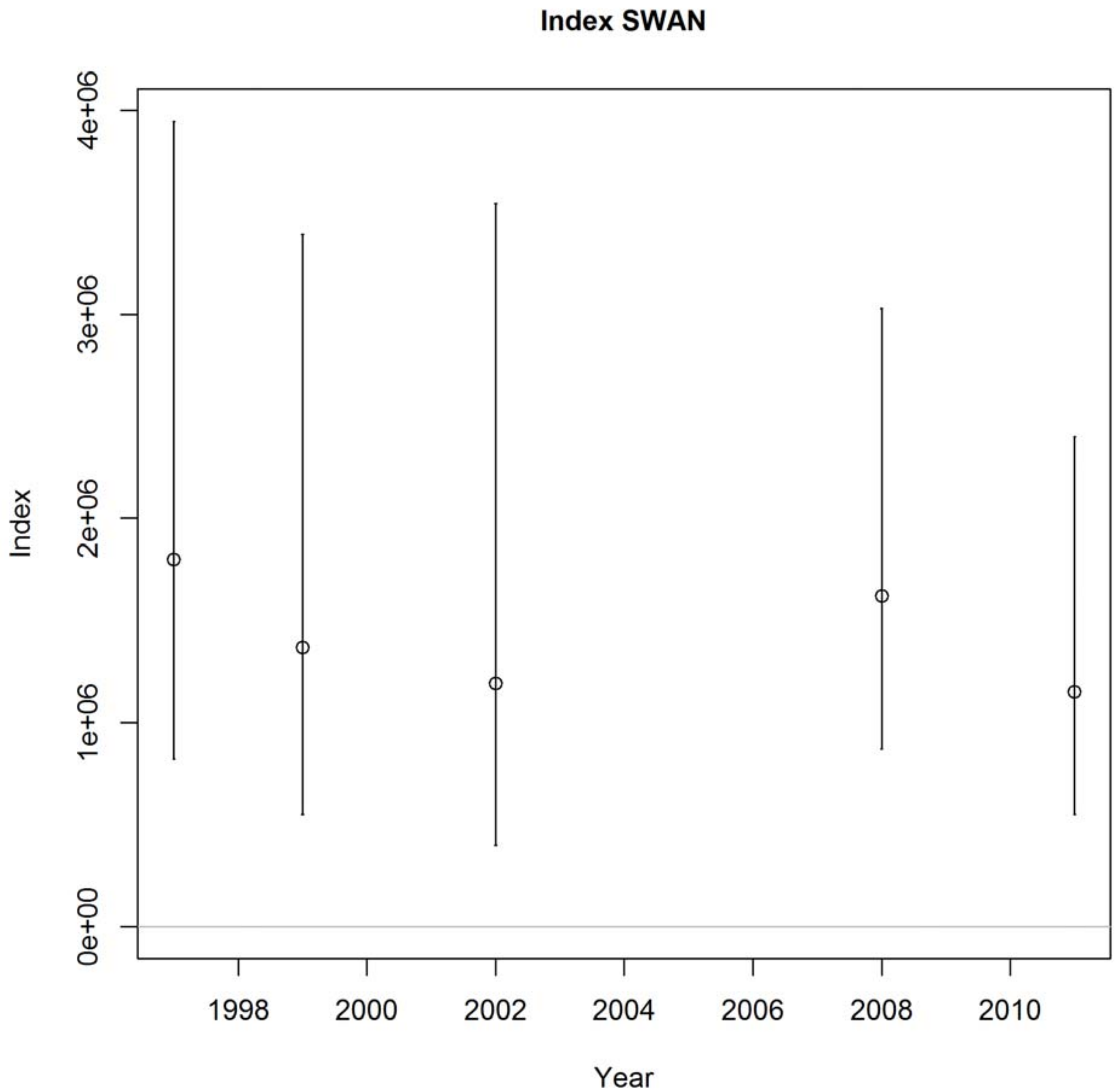
length comps, sexes combined, whole catch, aggregated across time by

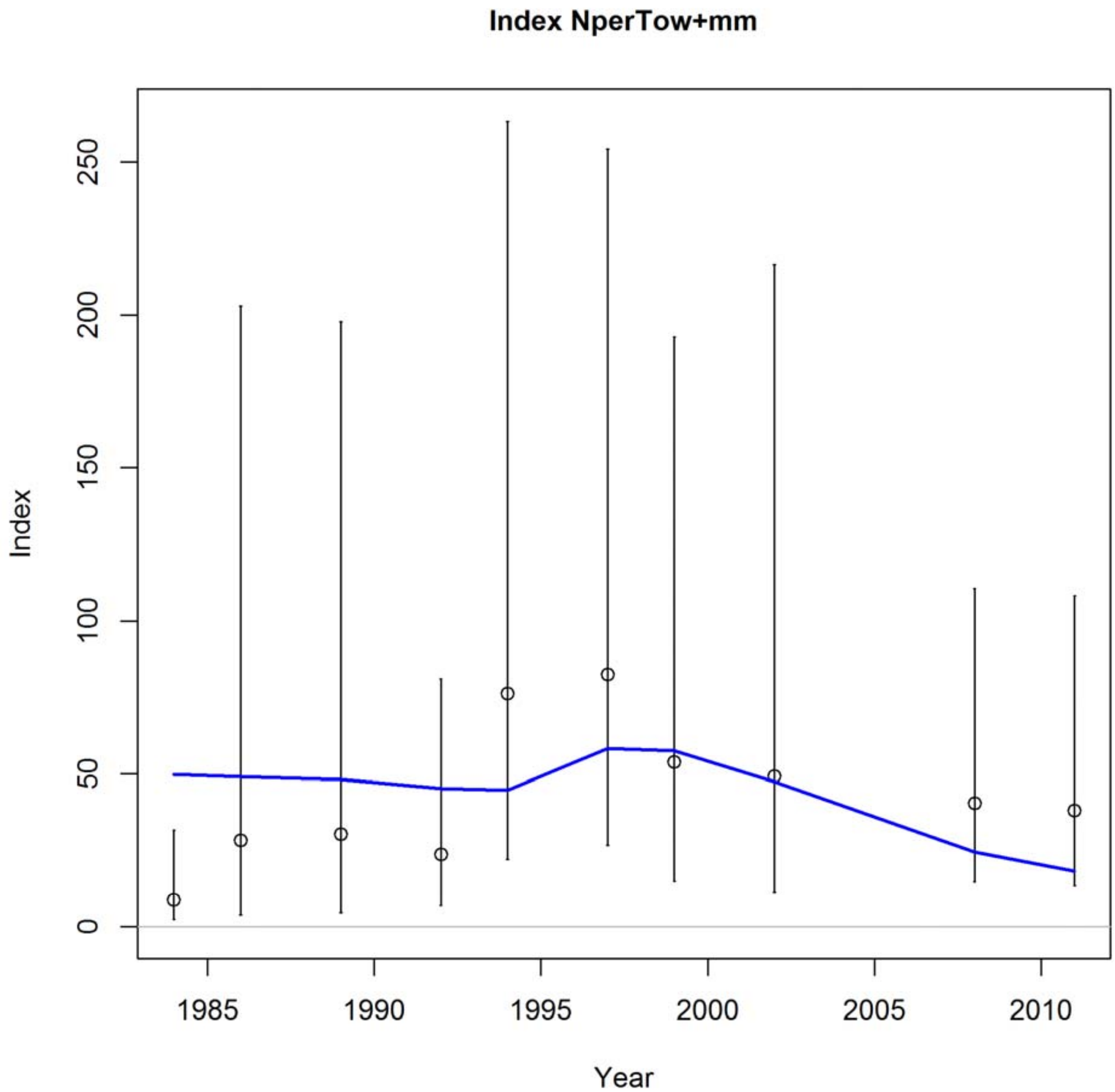


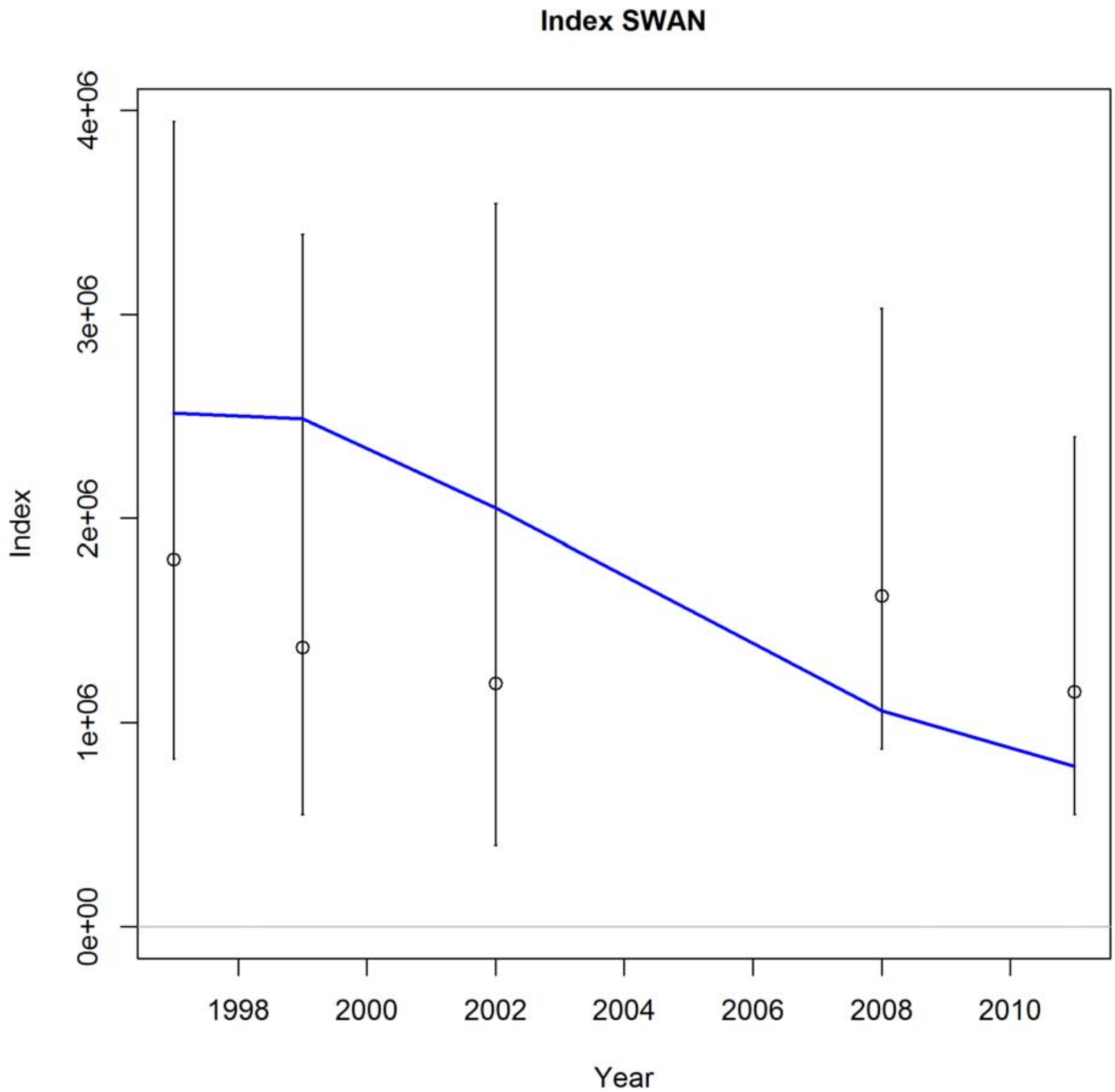


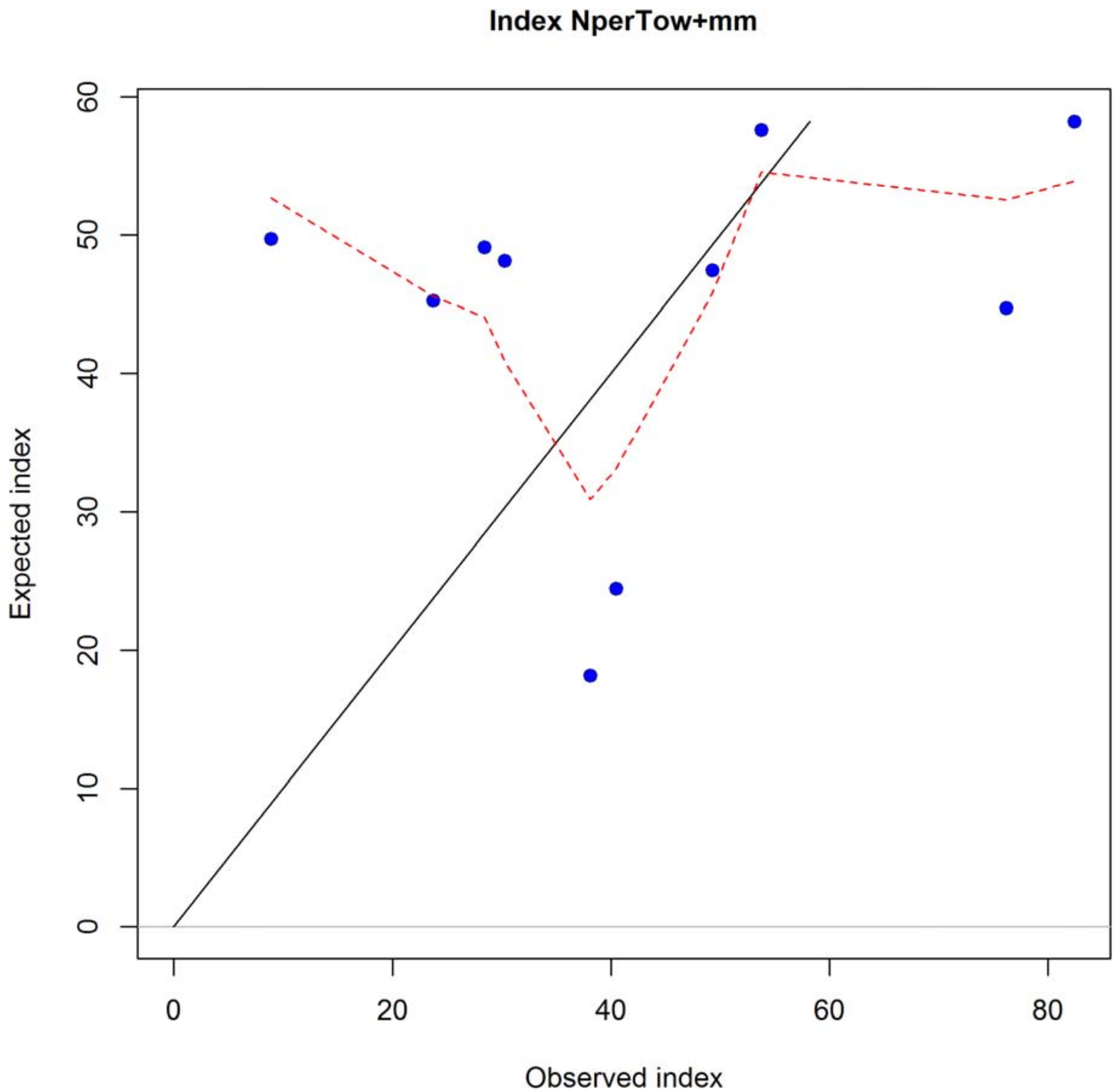
Data by type and year
Catch
Fishery
Abundance indices
NperTow+mm
SWAN
Length compositions
Fishery
NperTow+mm
Conditional age-at-length compositions
NperTow+mm
1985
1990
1995
2000
2005
2010
Year

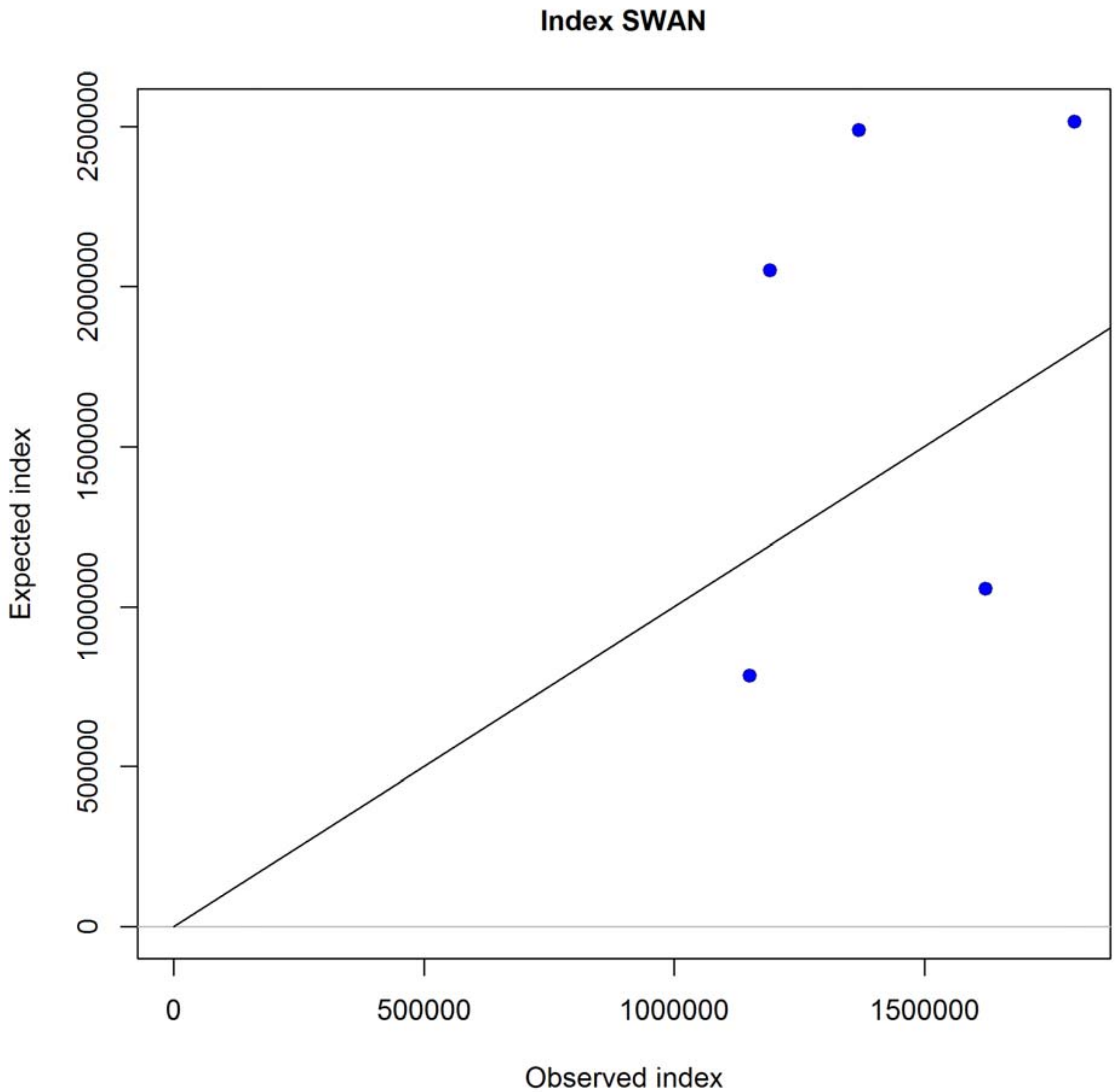

Index NperTow+mm
Index
0
50
100
150
200
250
1985
1990
1995
2000
2005
2010
Year


Index SWAN
Index
Year
4e+06
3e+06
2e+06
1e+06
0e+00
1998
2000
2002
2004
2006
2008
2010

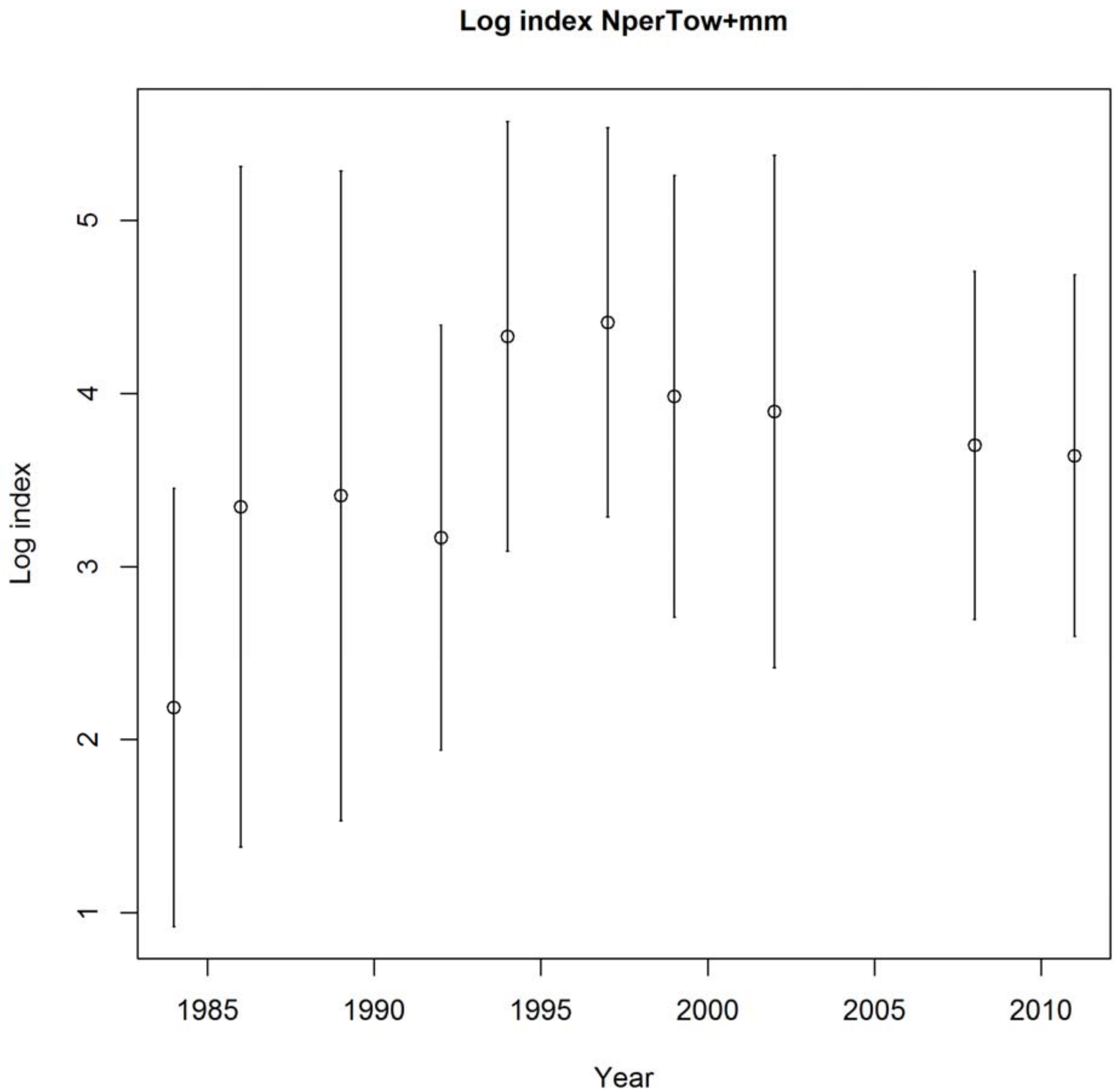

Index NperTow+mm
Index
0
50
100
150
200
250
1985
1990
1995
2000
2005
2010
Year

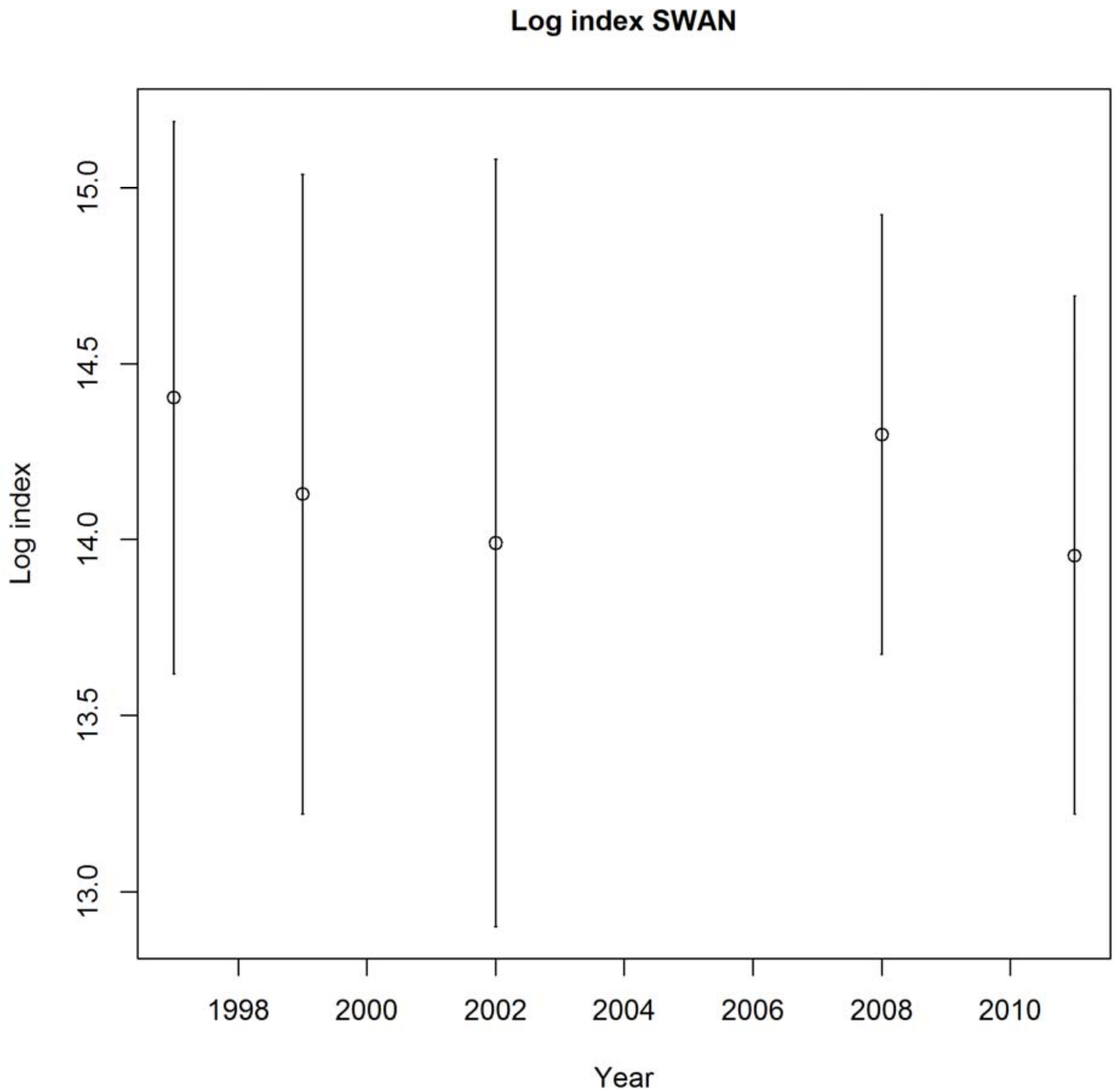

Index SWAN
Index
Year
0e+00
1e+06
2e+06
3e+06
4e+06
1998
2000
2002
2004
2006
2008
2010

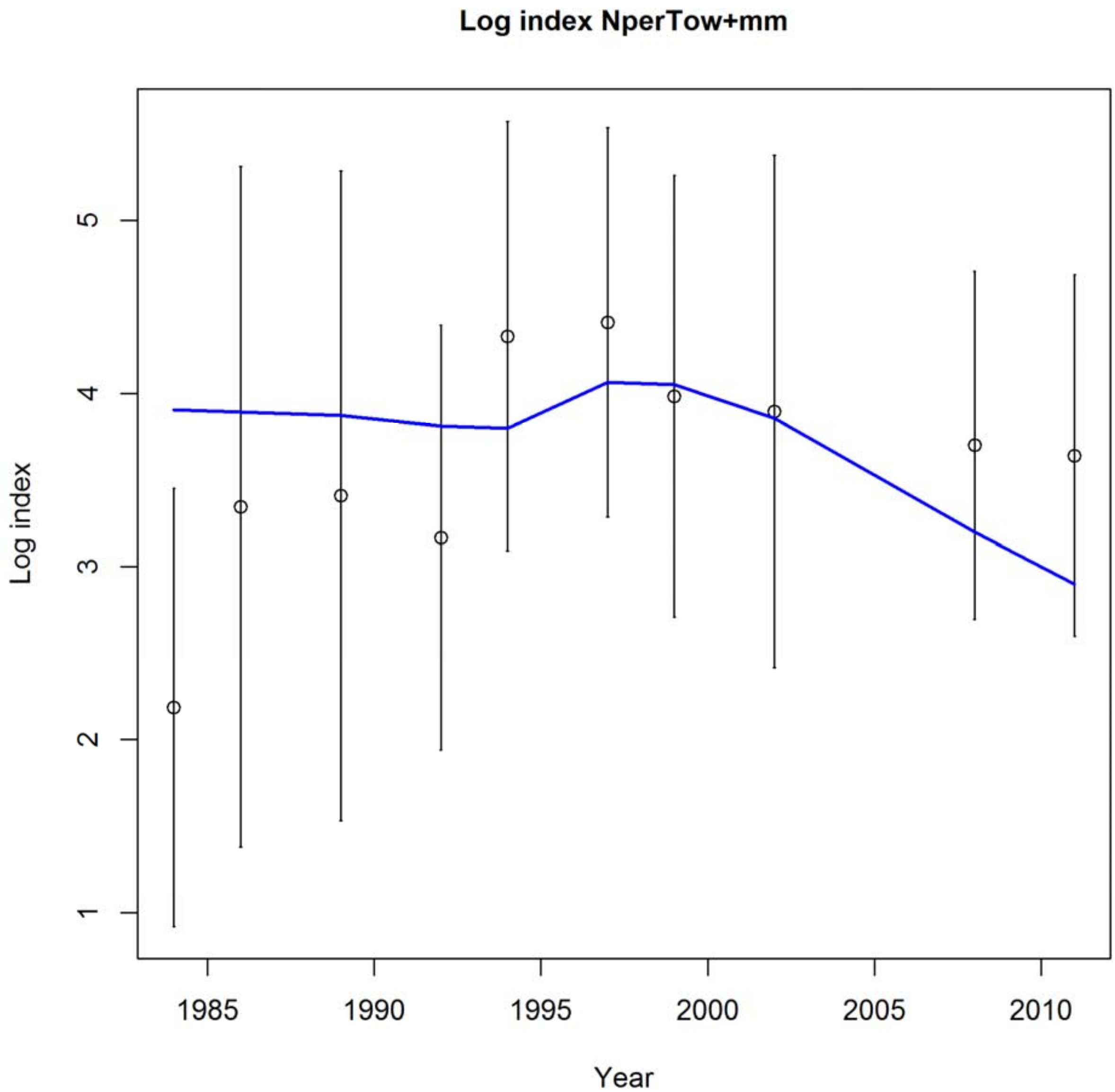

Index NperTow+mm
Expected index
Observed index
0
10
20
30
40
50
60
0
20
40
60
80

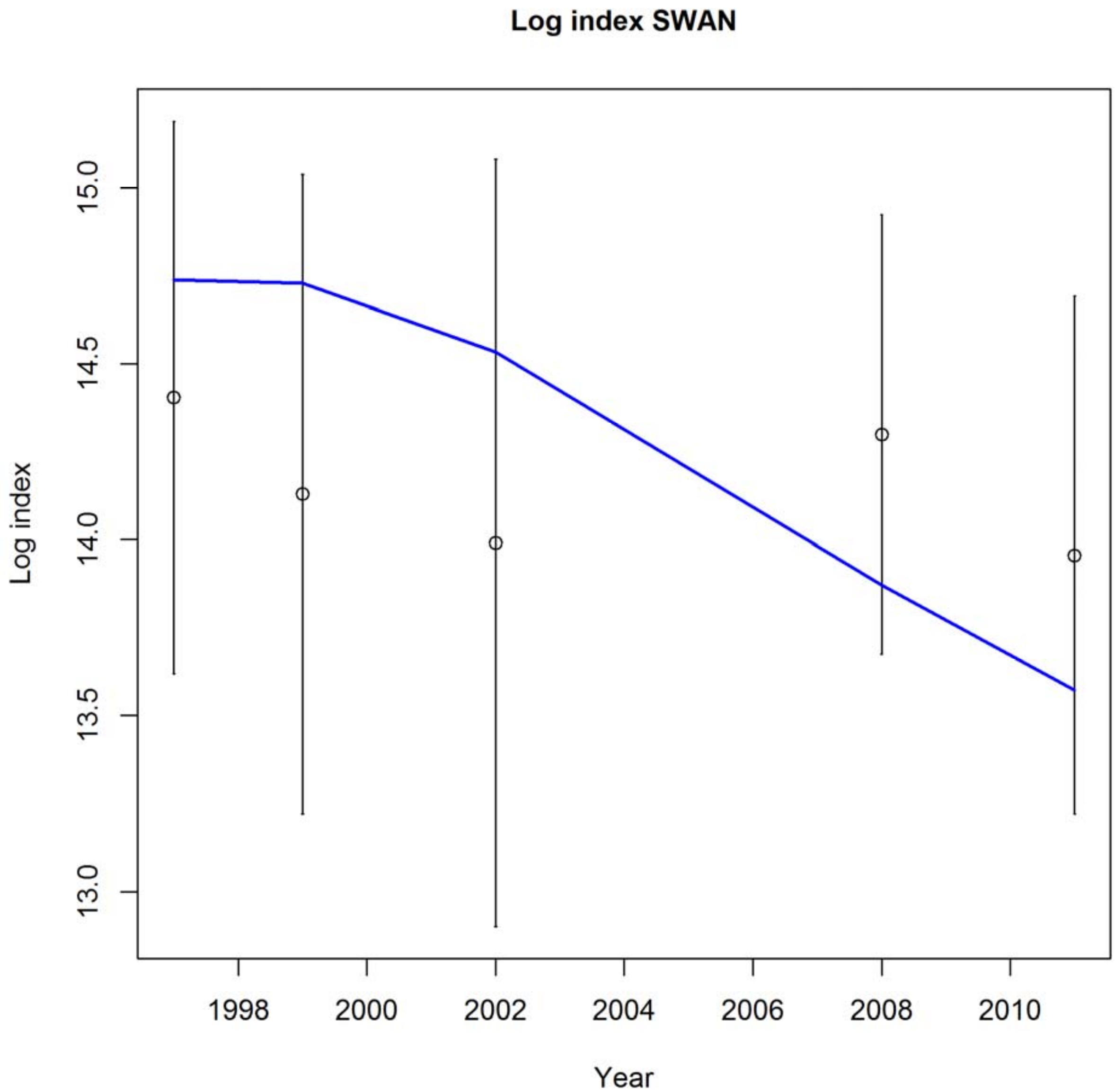


Index SWAN
Expected index
Observed index
0
500000
1000000
1500000
2000000
2500000
0
500000
1000000
1500000

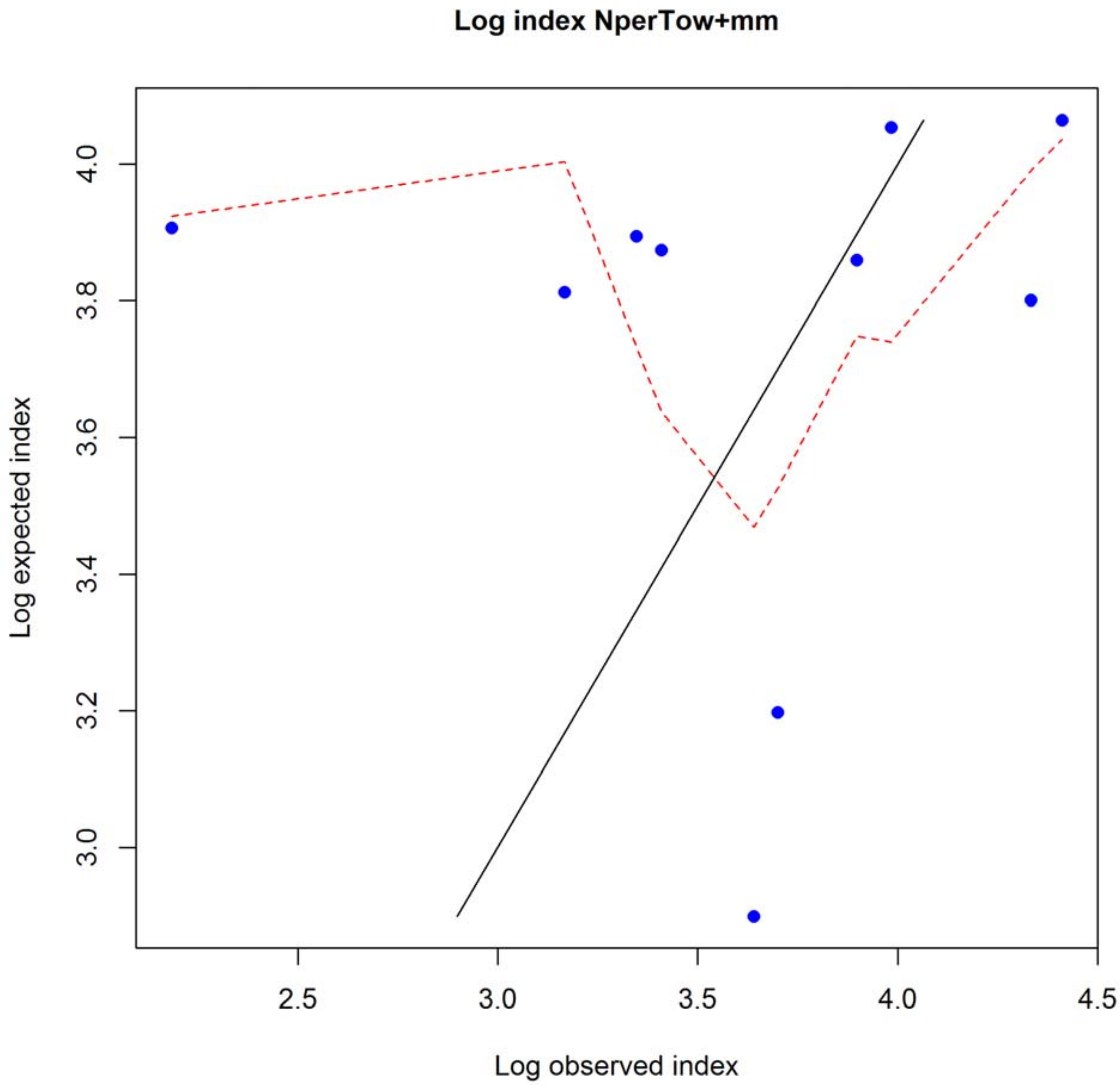

Log index NperTow+mm
Log index
Year
1
2
3
4
5
1985
1990
1995
2000
2005
2010

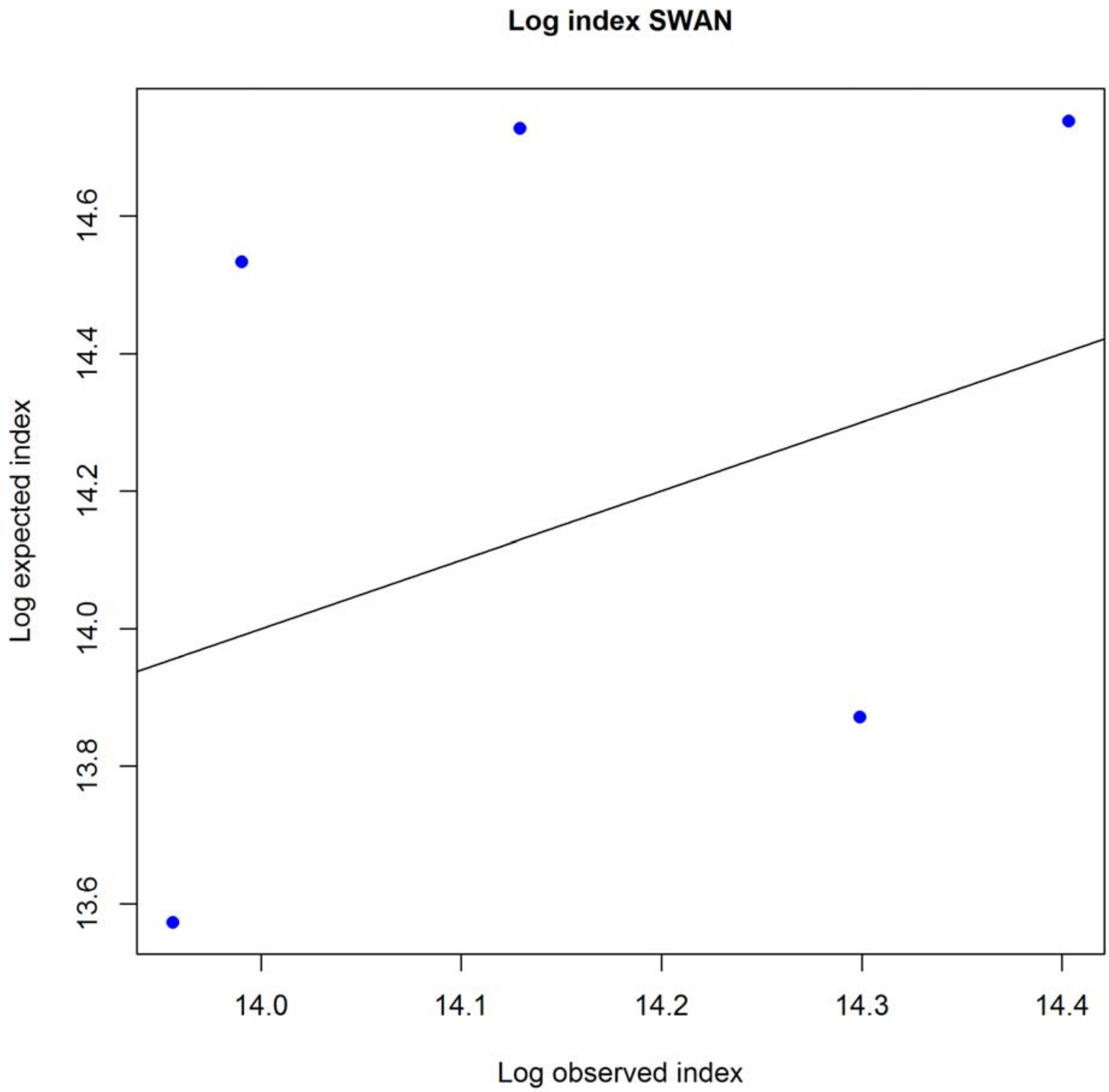

Log index SWAN
Log index
15.0
14.5
14.0
13.5
13.0
1998
2000
2002
2004
2006
2008
2010
Year

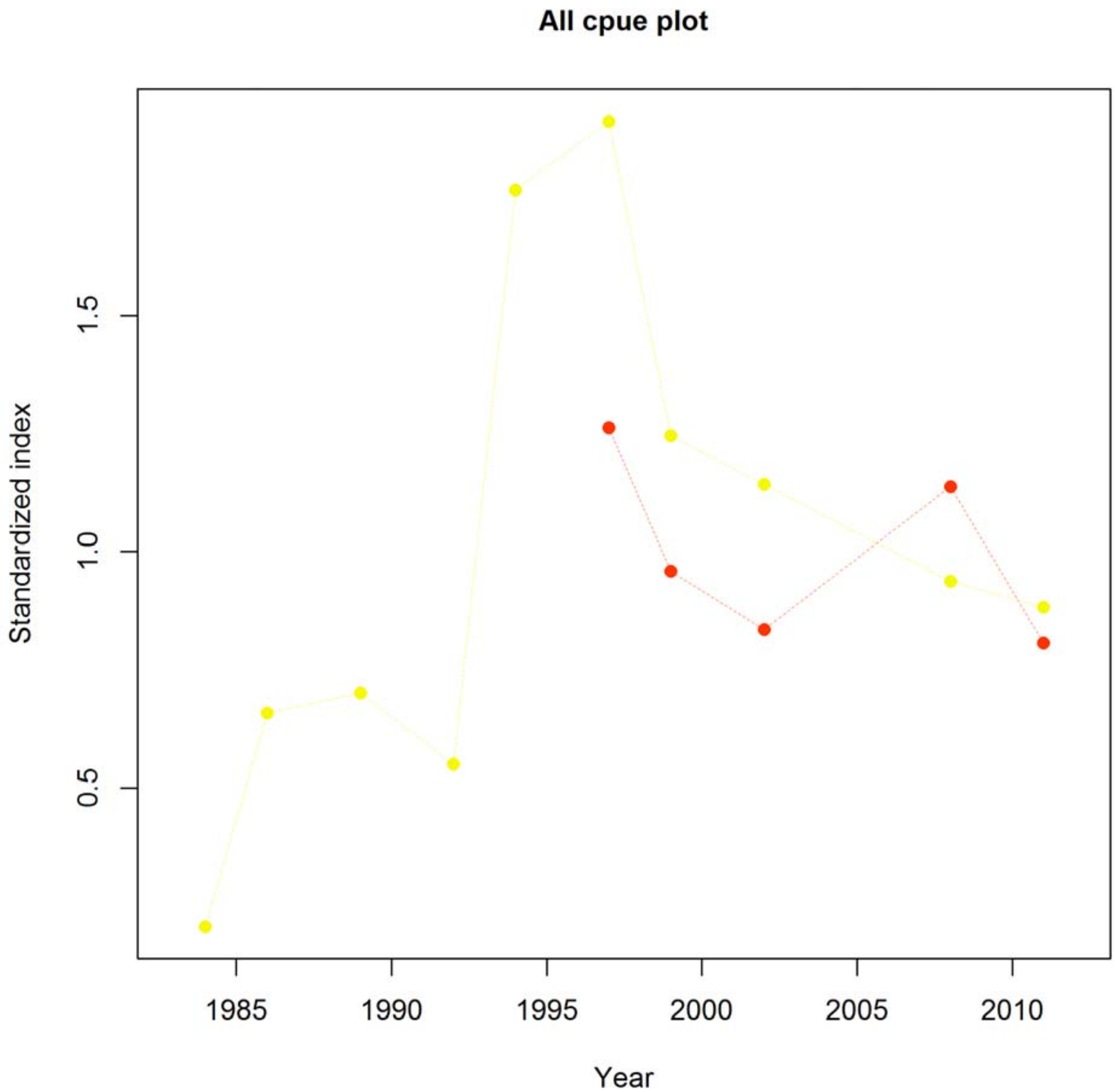

Log index NperTow+mm
Log index
Year
1
2
3
4
5
1985
1990
1995
2000
2005
2010

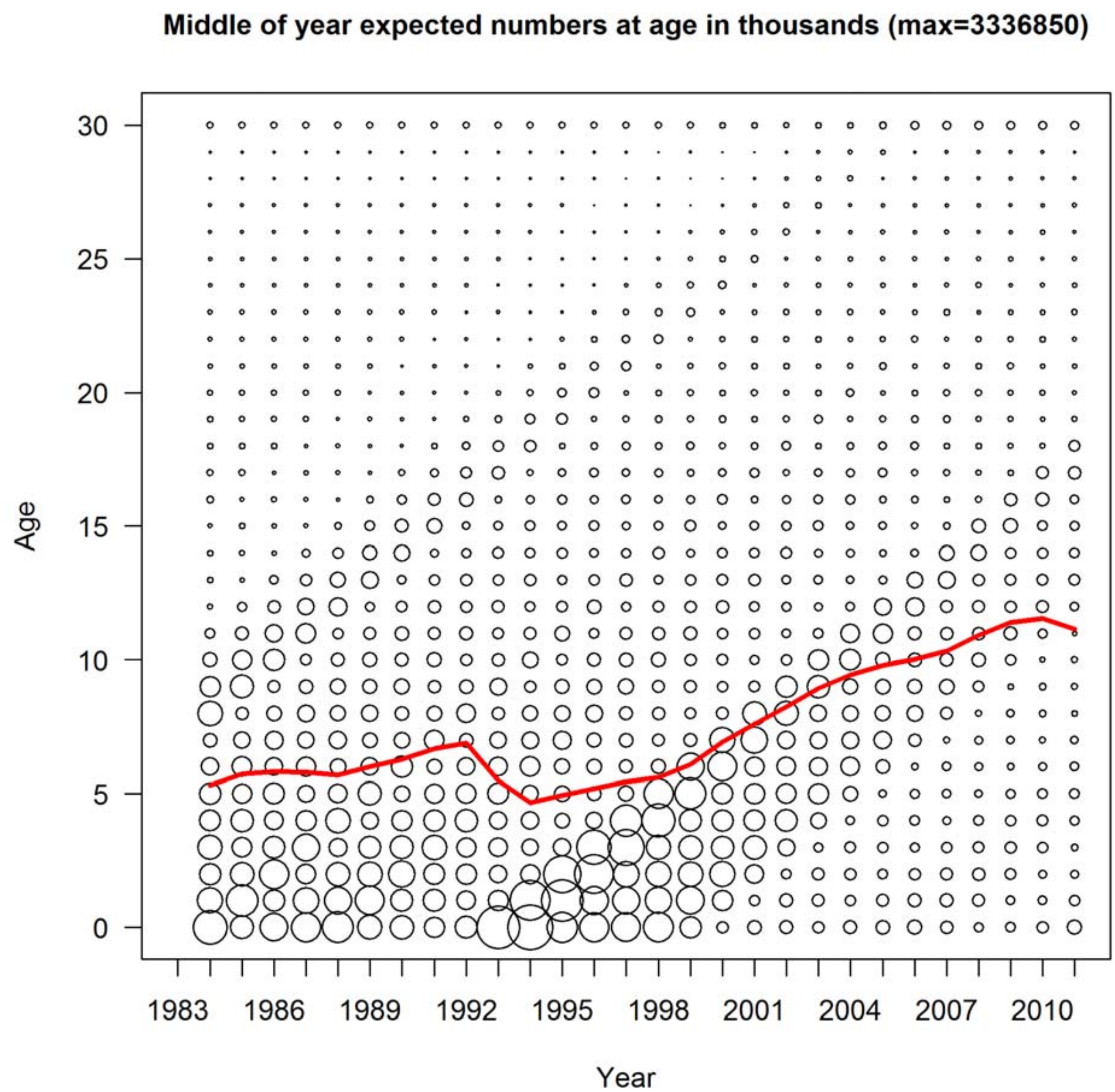


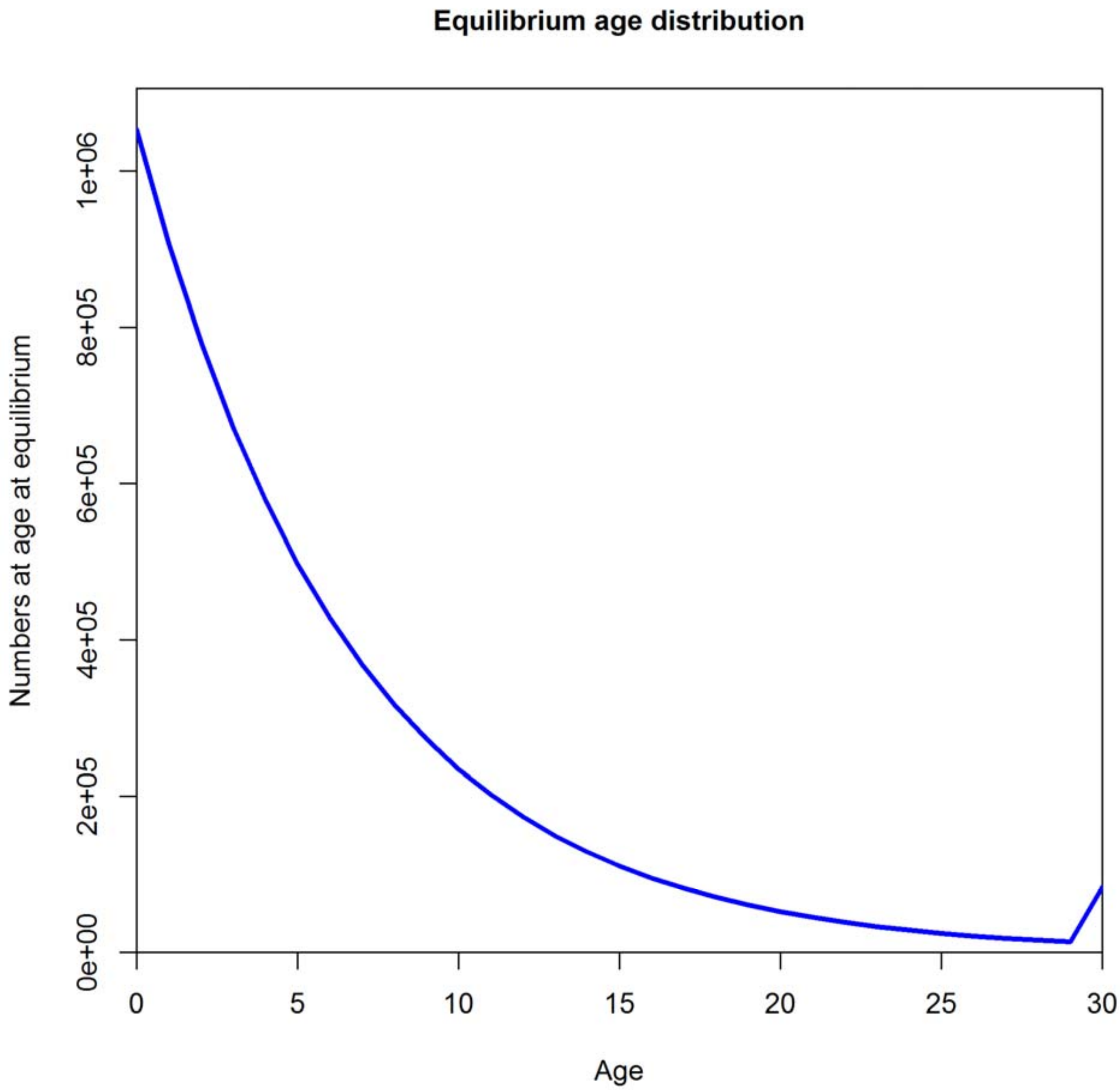
Log index SWAN
Log index
15.0
14.5
14.0
13.5
13.0
1998
2000
2002
2004
2006
2008
2010
Year


Log index NperTow+mm
Log expected index
Log observed index
4.0
3.8
3.6
3.4
3.2
3.0
2.5
3.0
3.5
4.0
4.5

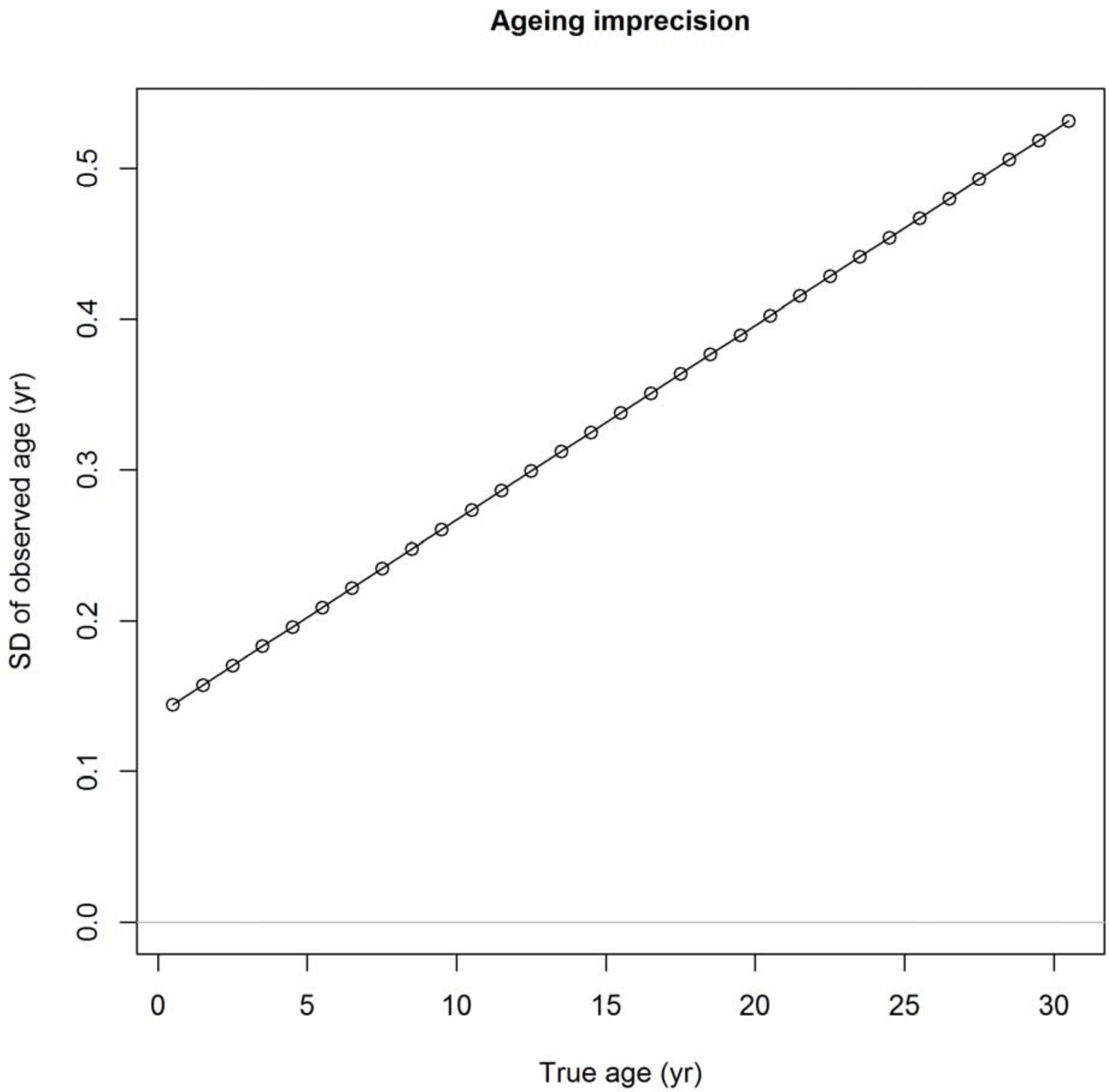

Log index SWAN
Log expected index
Log observed index
14.0
14.1
14.2
14.3
14.4
13.6
13.8
14.0
14.2
14.4
14.6


All cpue plot
Standardized index
0.5
1.0
1.5
1985
1990
1995
2000
2005
2010
Year

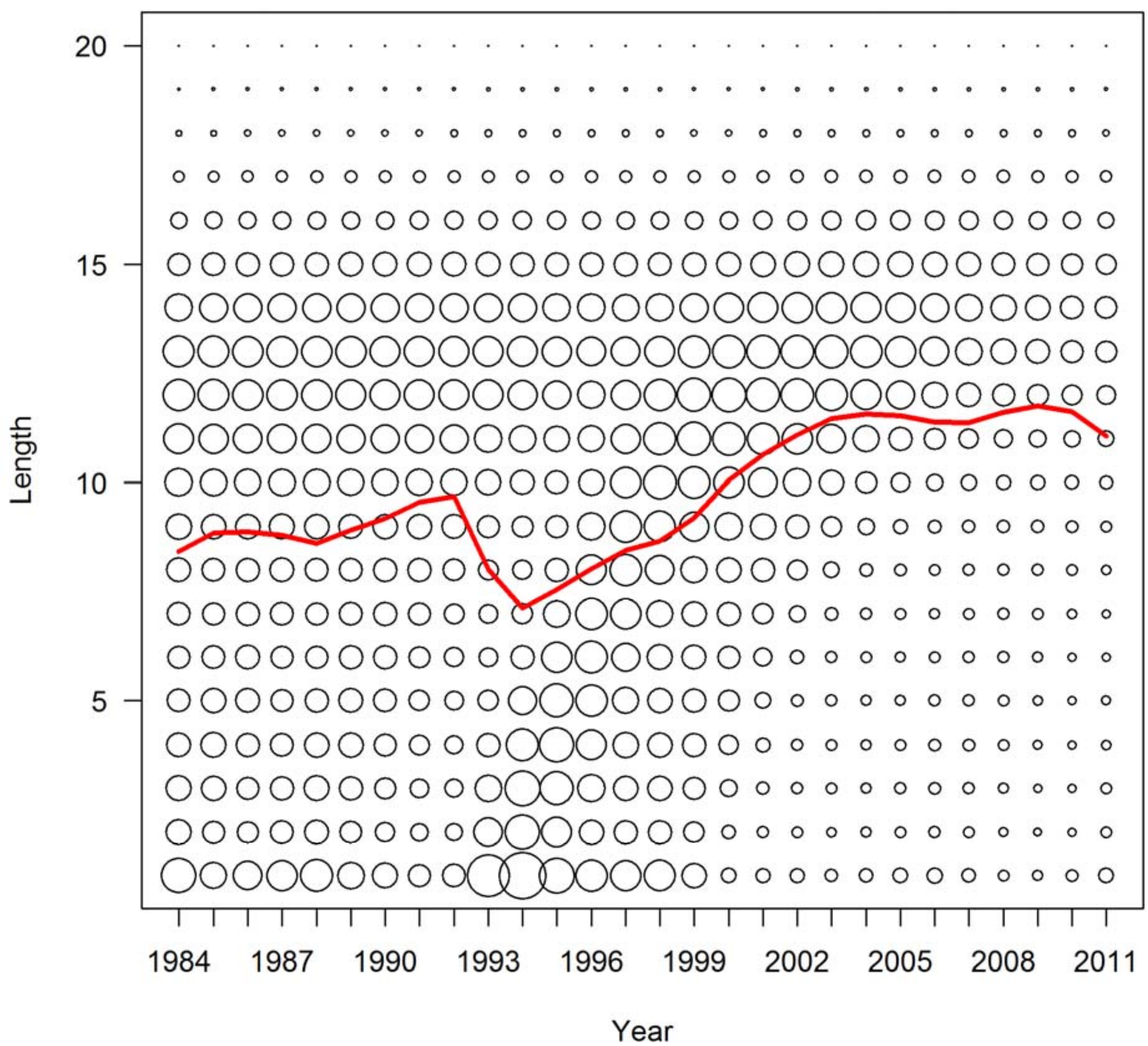

Middle of year expected numbers at age in thousands (max=3336850)
Age
30
25
20
15
10
5
0
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
Year

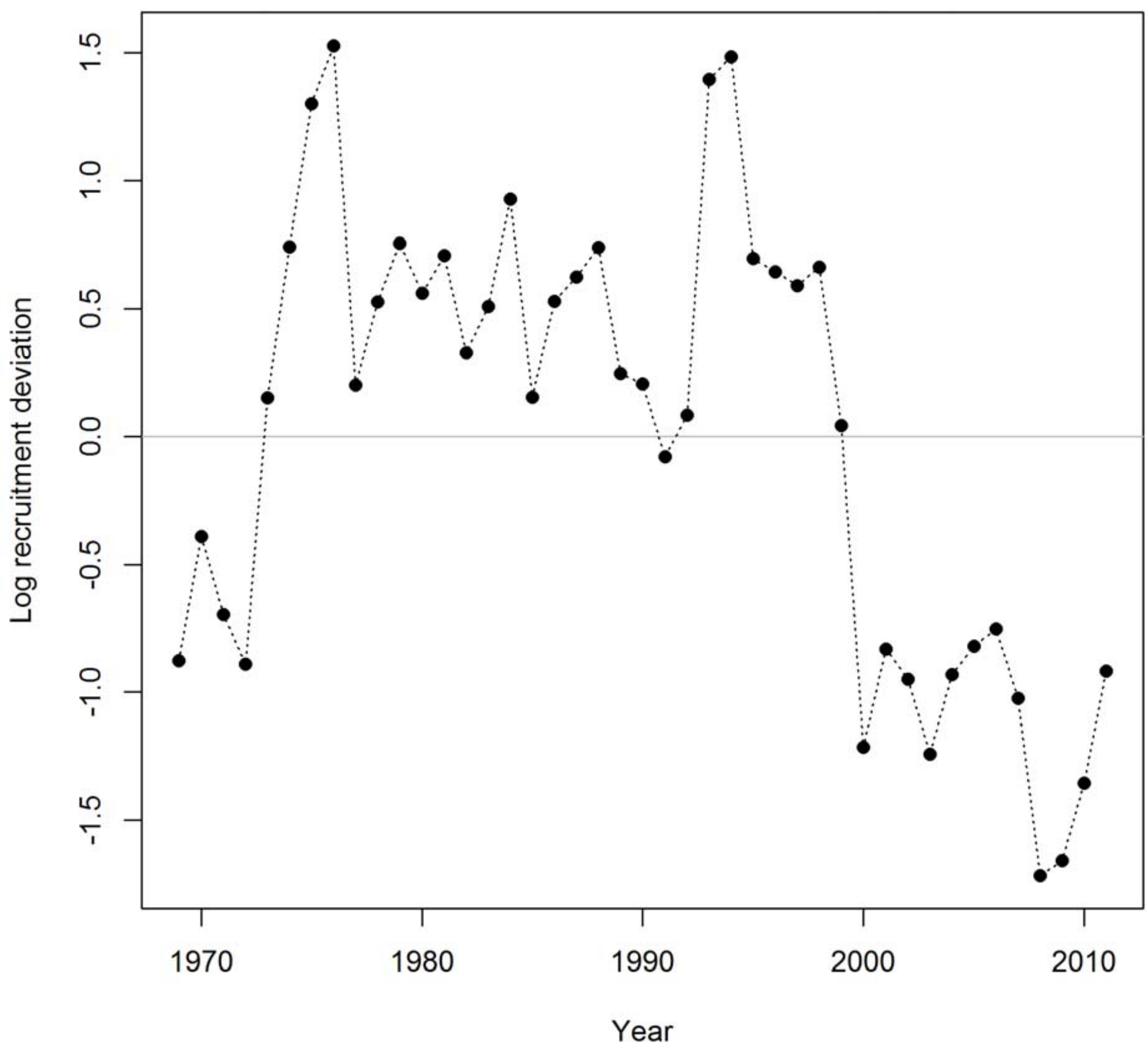


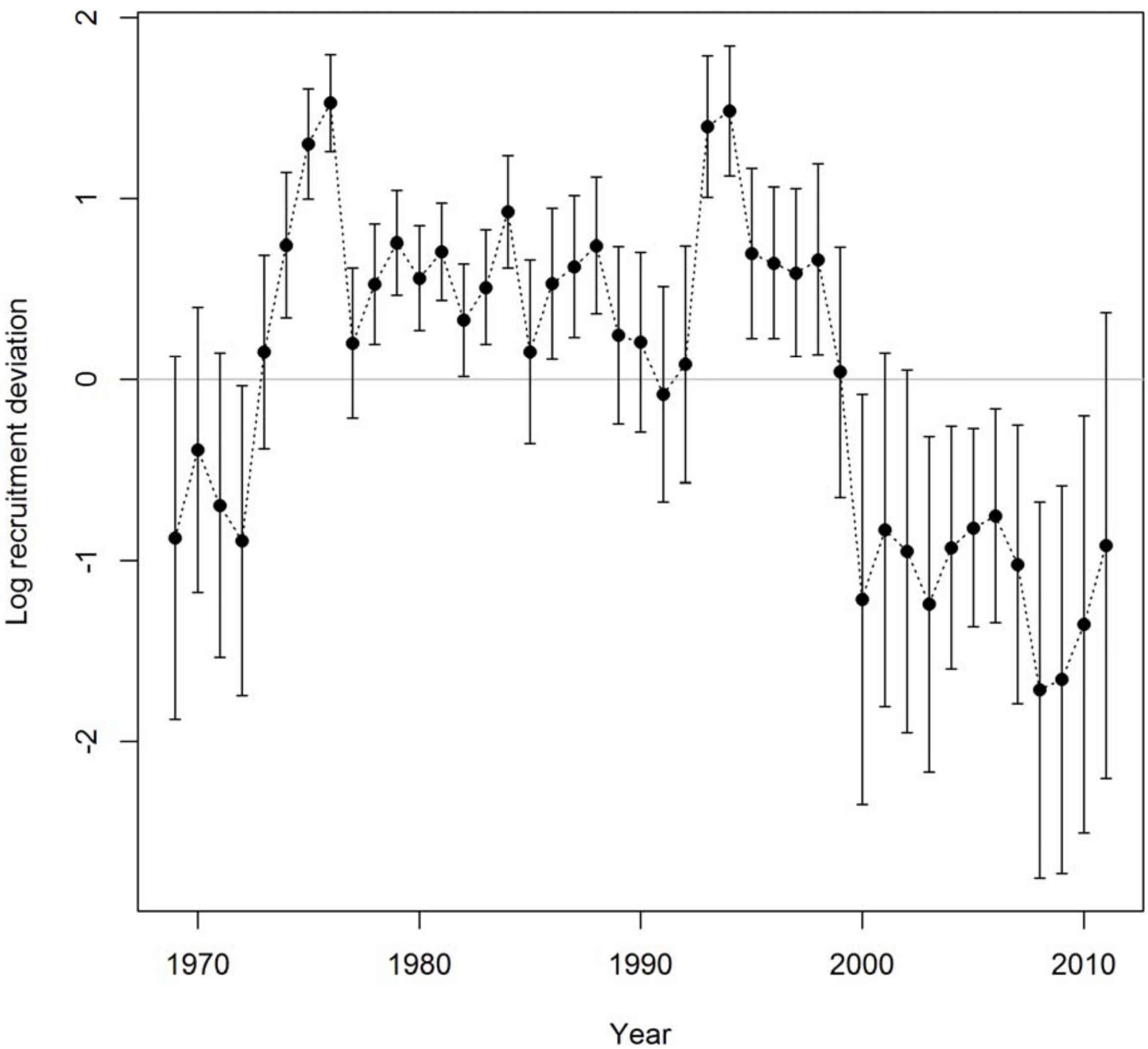
Equilibrium age distribution
Numbers at age at equilibrium
0e+00
2e+05
4e+05
6e+05
8e+05
1e+06
0
5
10
15
20
25
30
Age


Ageing imprecision
SD of observed age (yr)
0.0
0.1
0.2
0.3
0.4
0.5
0
5
10
15
20
25
30
True age (yr)

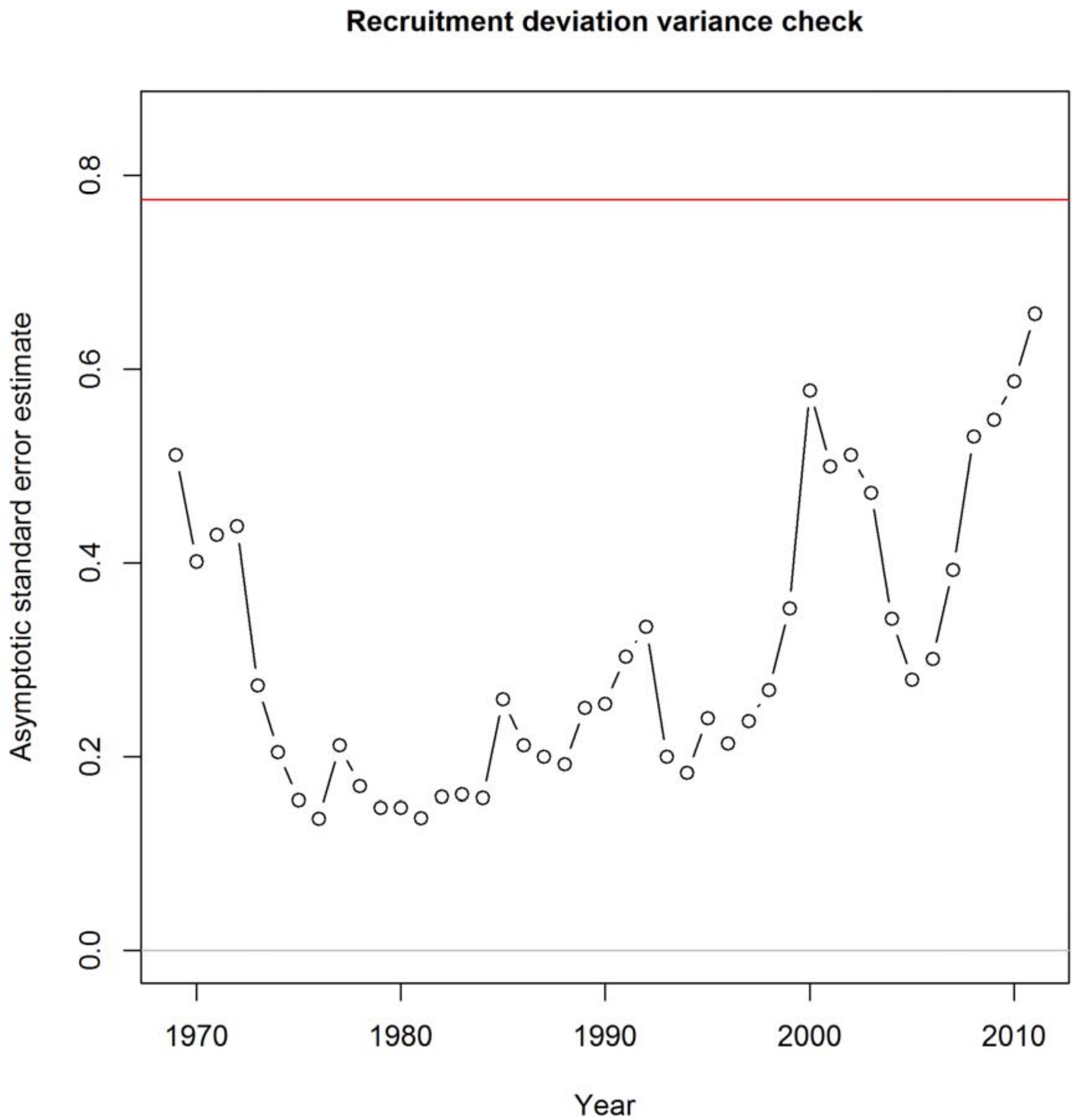
Middle of year expected numbers at length in thousands (max=1977530)

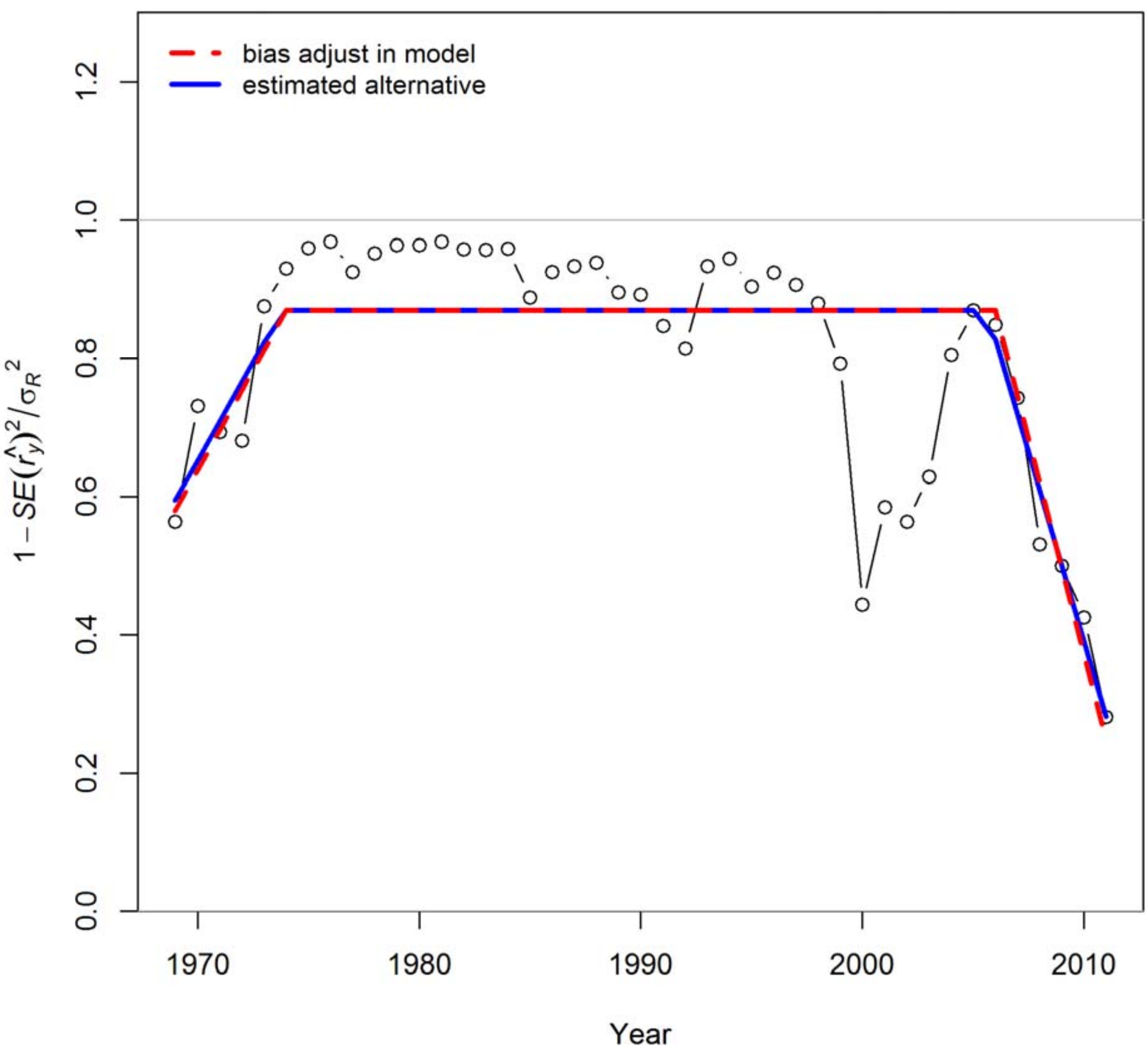


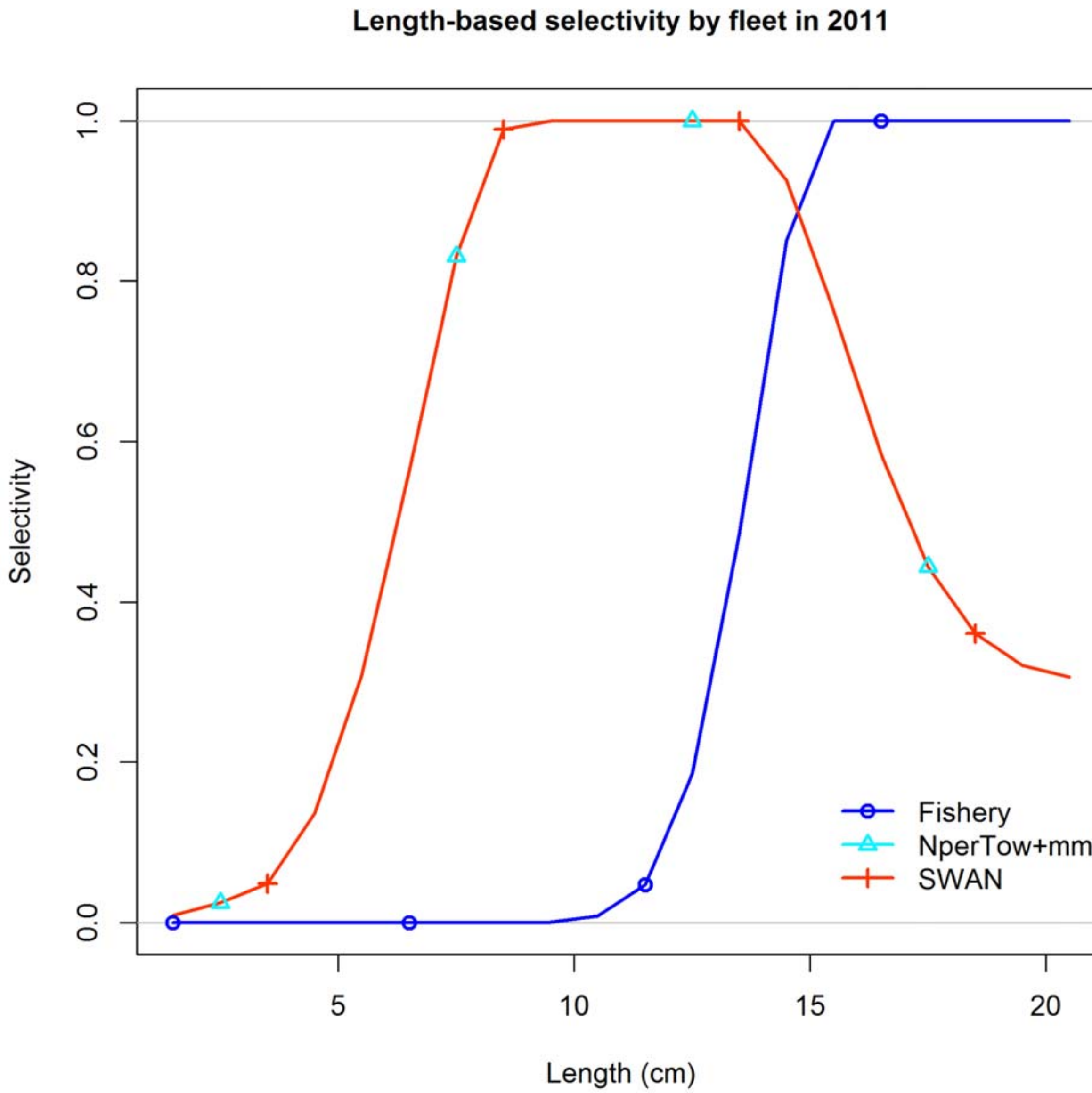

Log recruitment deviation
-1.5
-1.0
-0.5
0.0
0.5
1.0
1.5
1970
1980
1990
2000
2010
Year

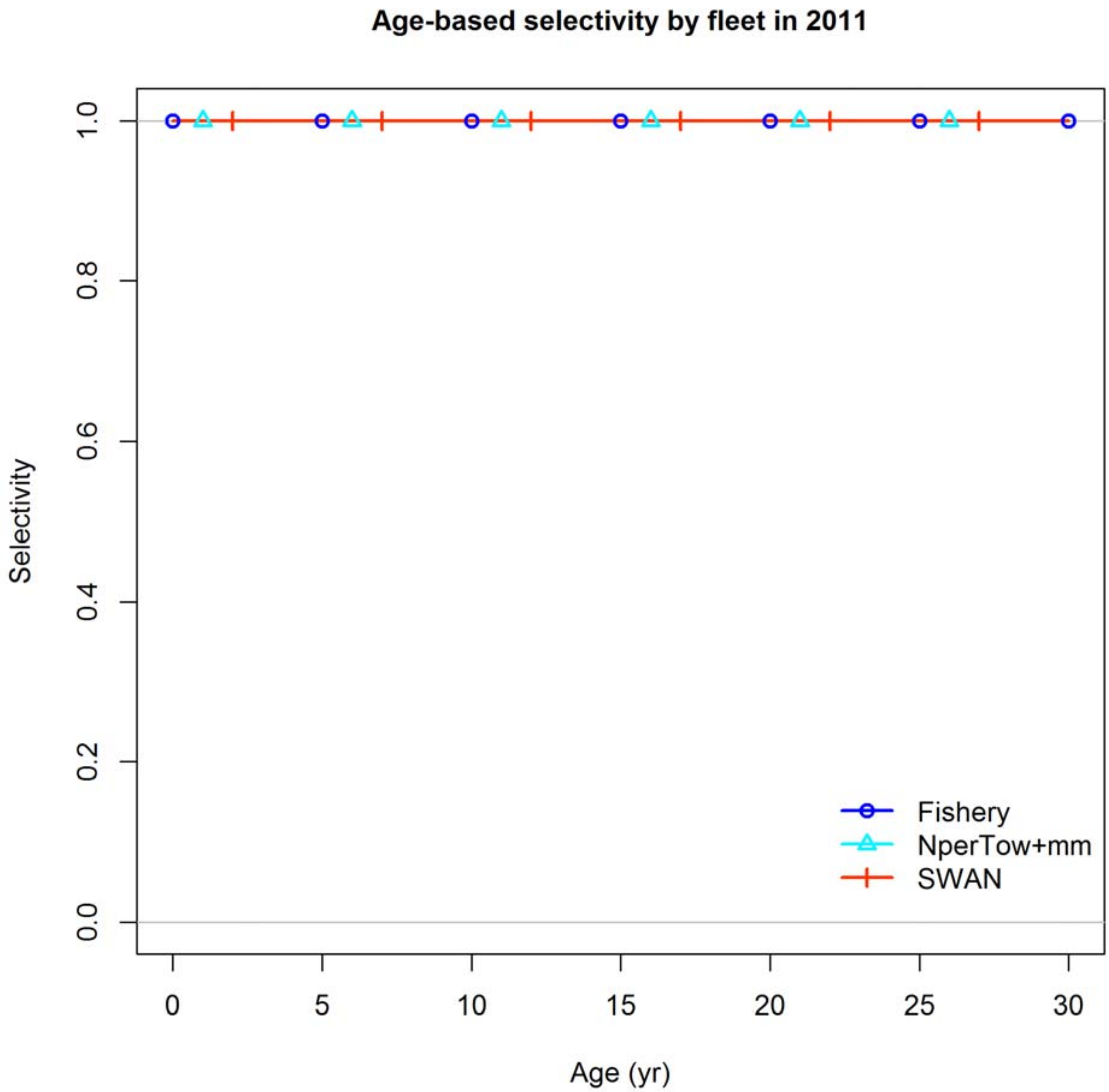


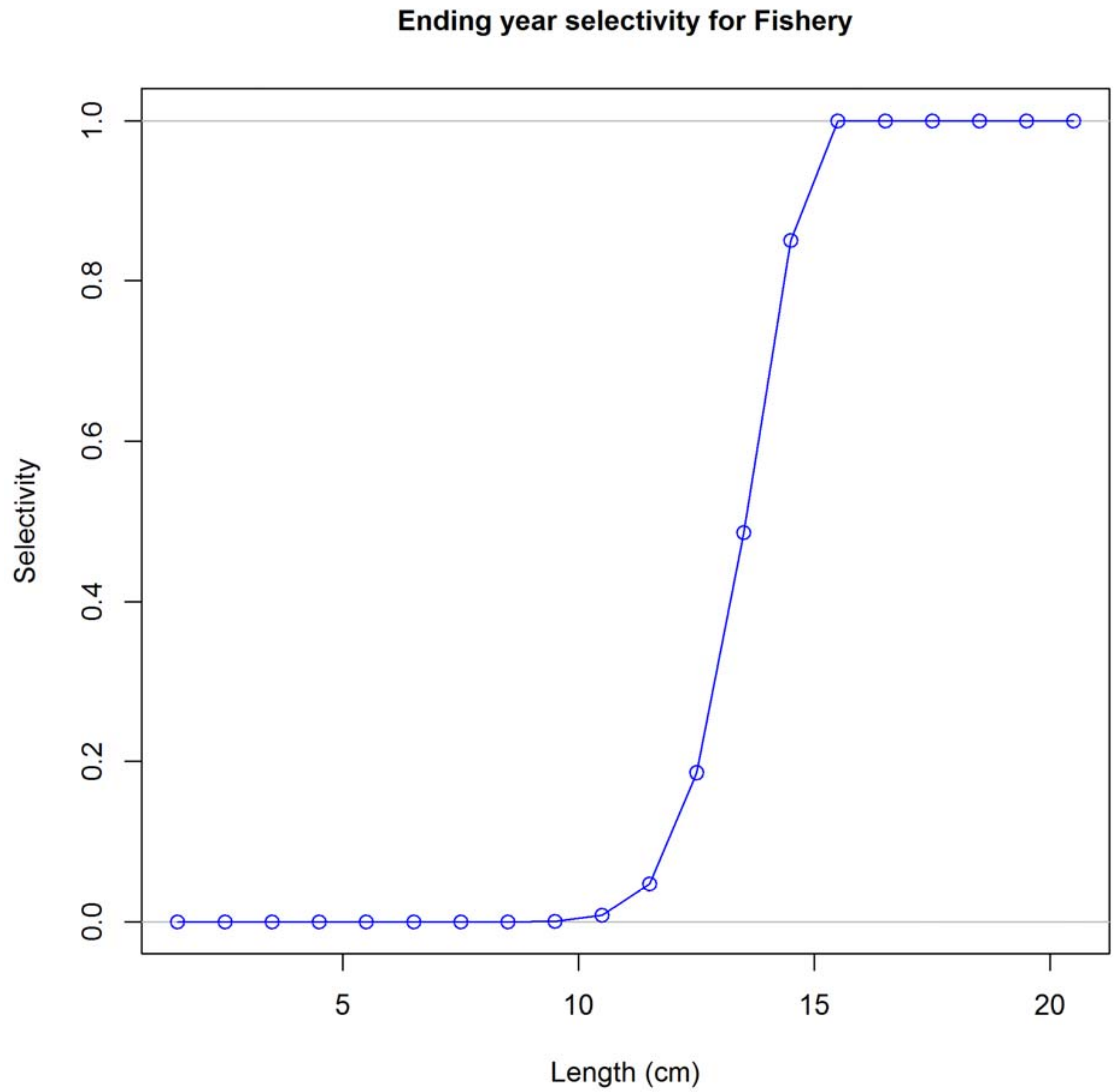
Log recruitment deviation
2
1
0
-1
-2
1970
1980
1990
2000
2010
Year

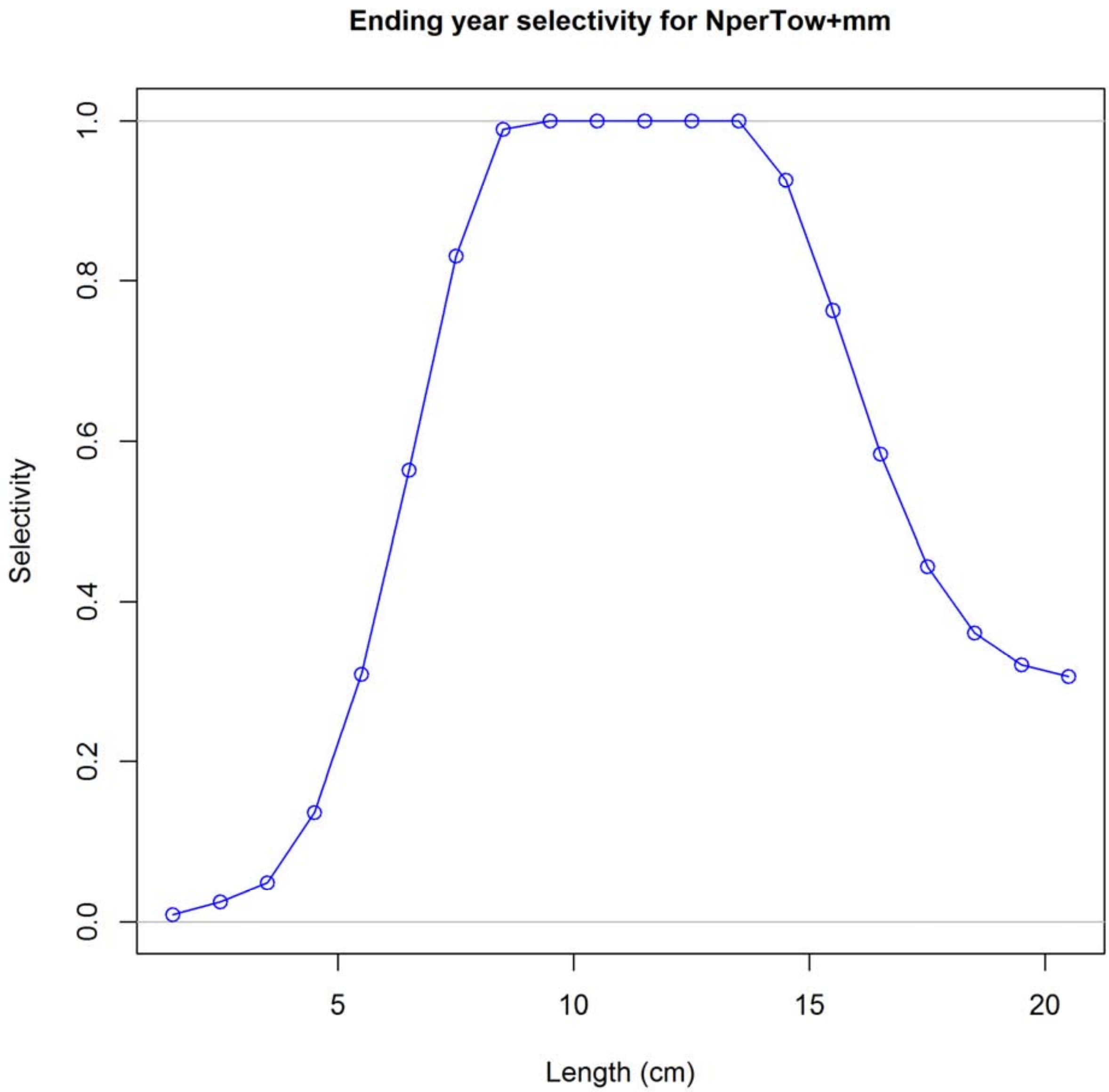

Recruitment deviation variance check
Asymptotic standard error estimate
0.0
0.2
0.4
0.6
0.8
1970
1980
1990
2000
2010
Year

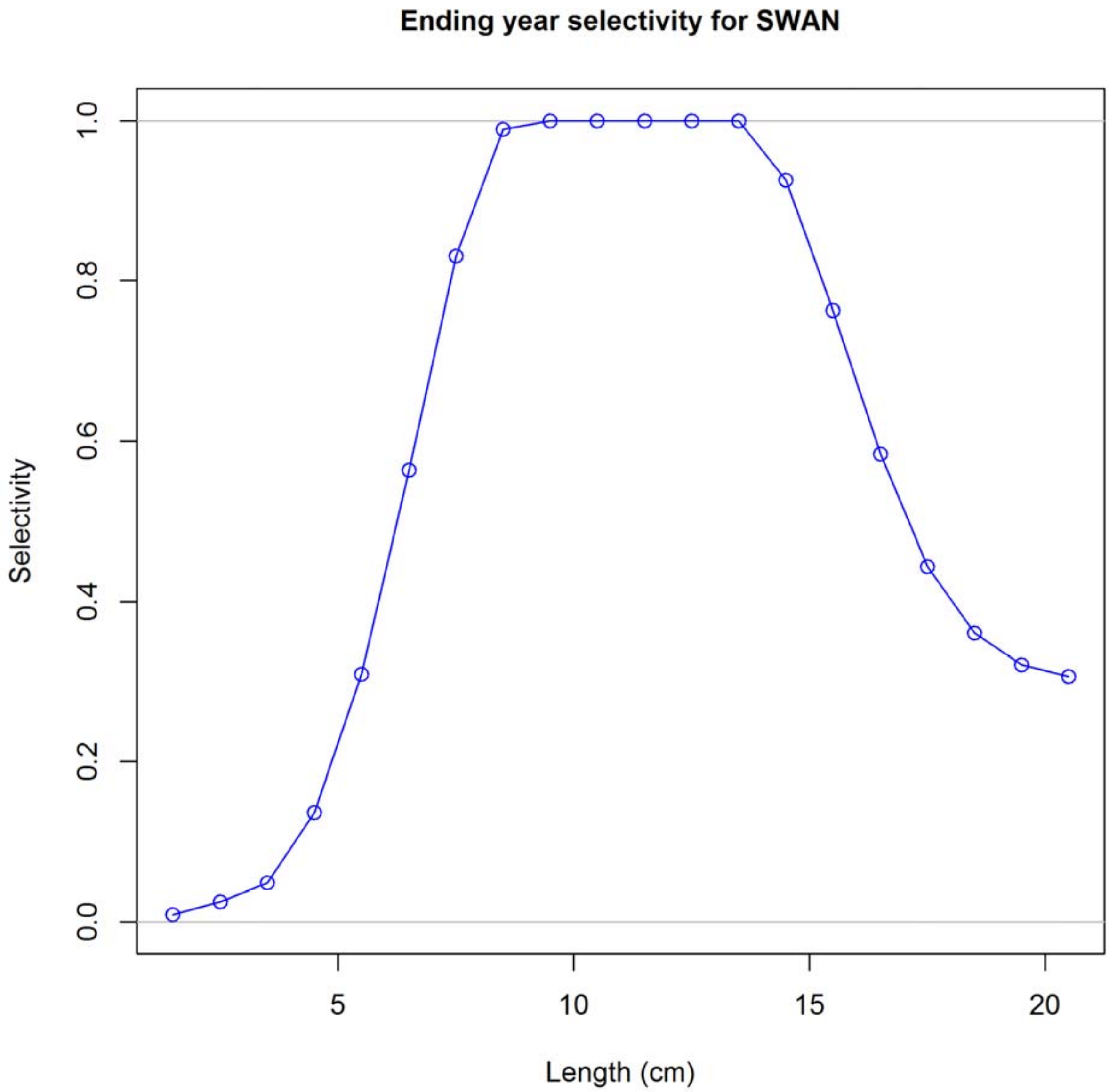

bias adjust in model
estimated alternative
$1 - SE(\hat{r}_y)^2/\sigma_R^2$
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1970
1980
1990
2000
2010
Year

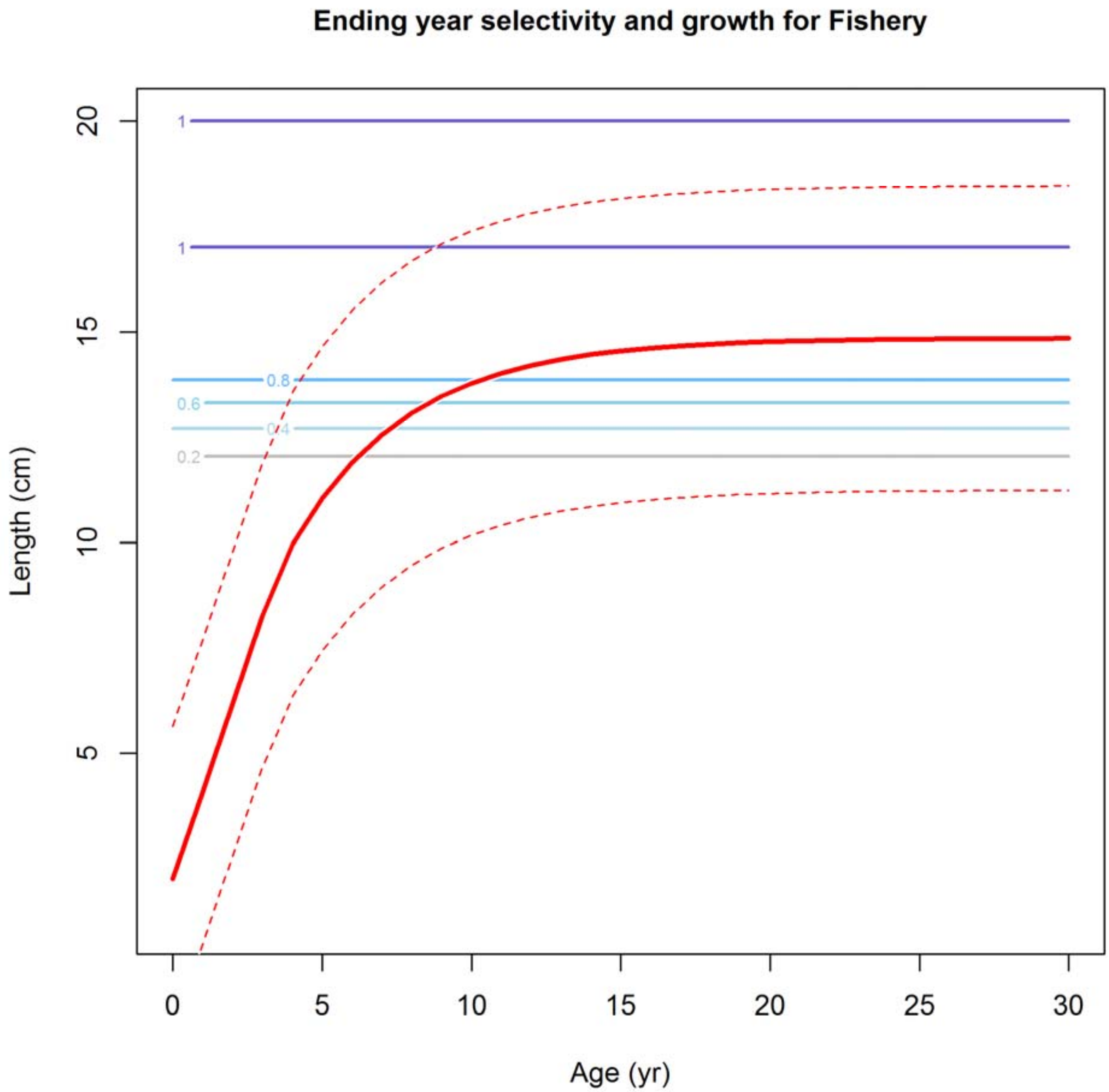

Length-based selectivity by fleet in 2011
Selectivity
Length (cm)
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
Fishery
NperTow+mm
SWAN

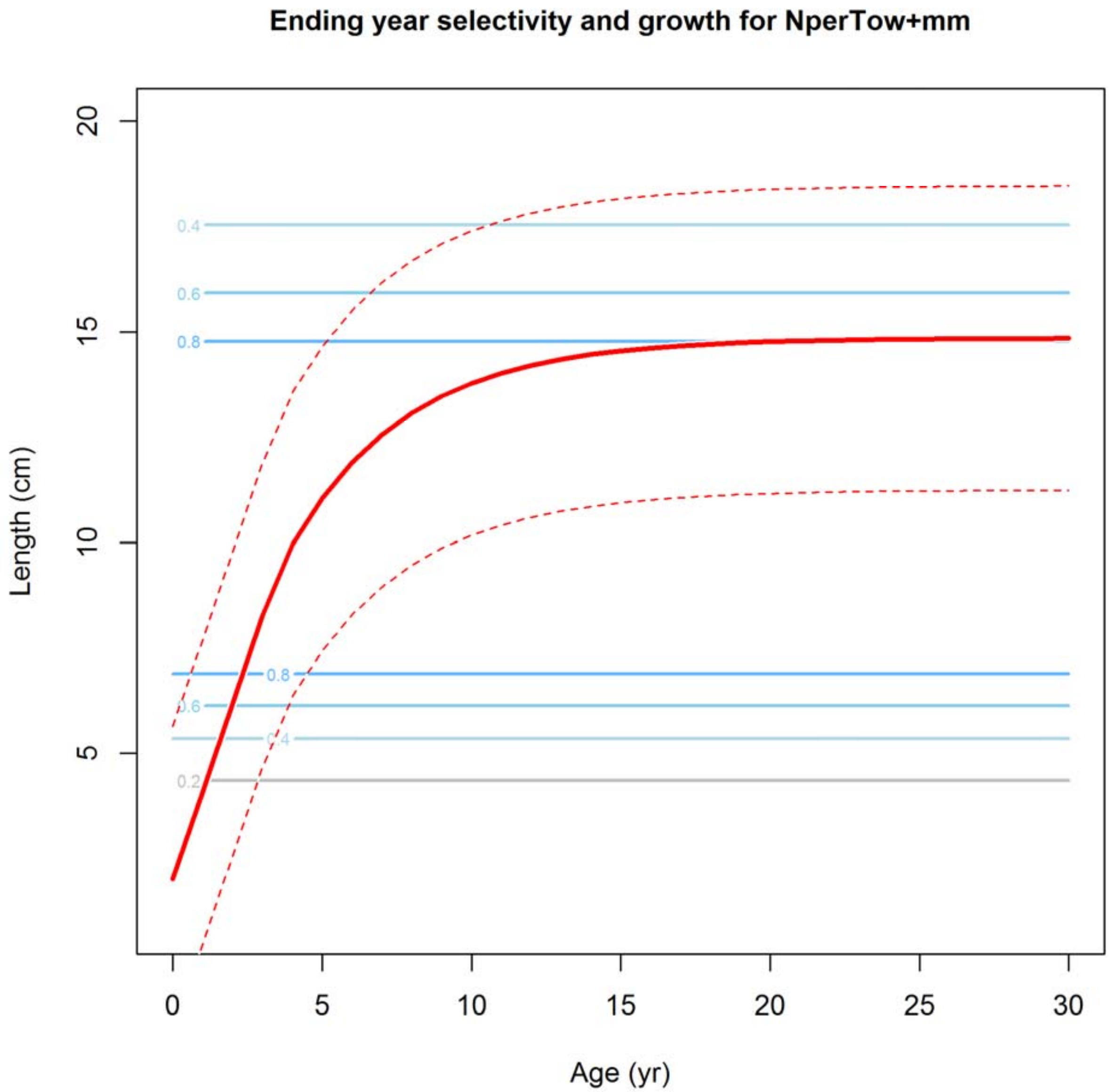

Age-based selectivity by fleet in 2011
Selectivity
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
Age (yr)
Fishery
NperTow+mm
SWAN


Ending year selectivity for Fishery
Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
Length (cm)

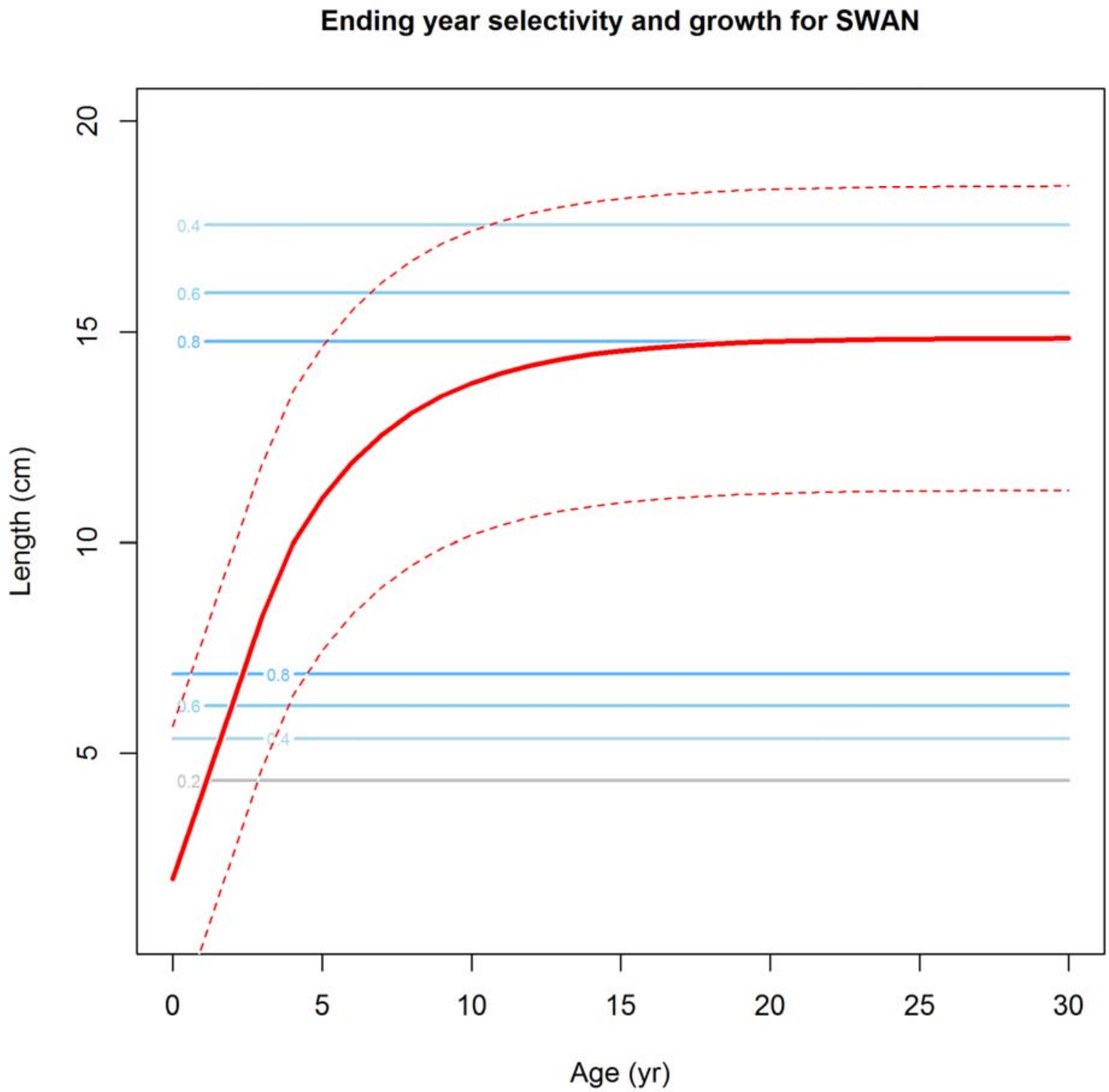

Ending year selectivity for NperTow+mm
Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
Length (cm)


Ending year selectivity for SWAN
Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
5
10
15
20
Length (cm)

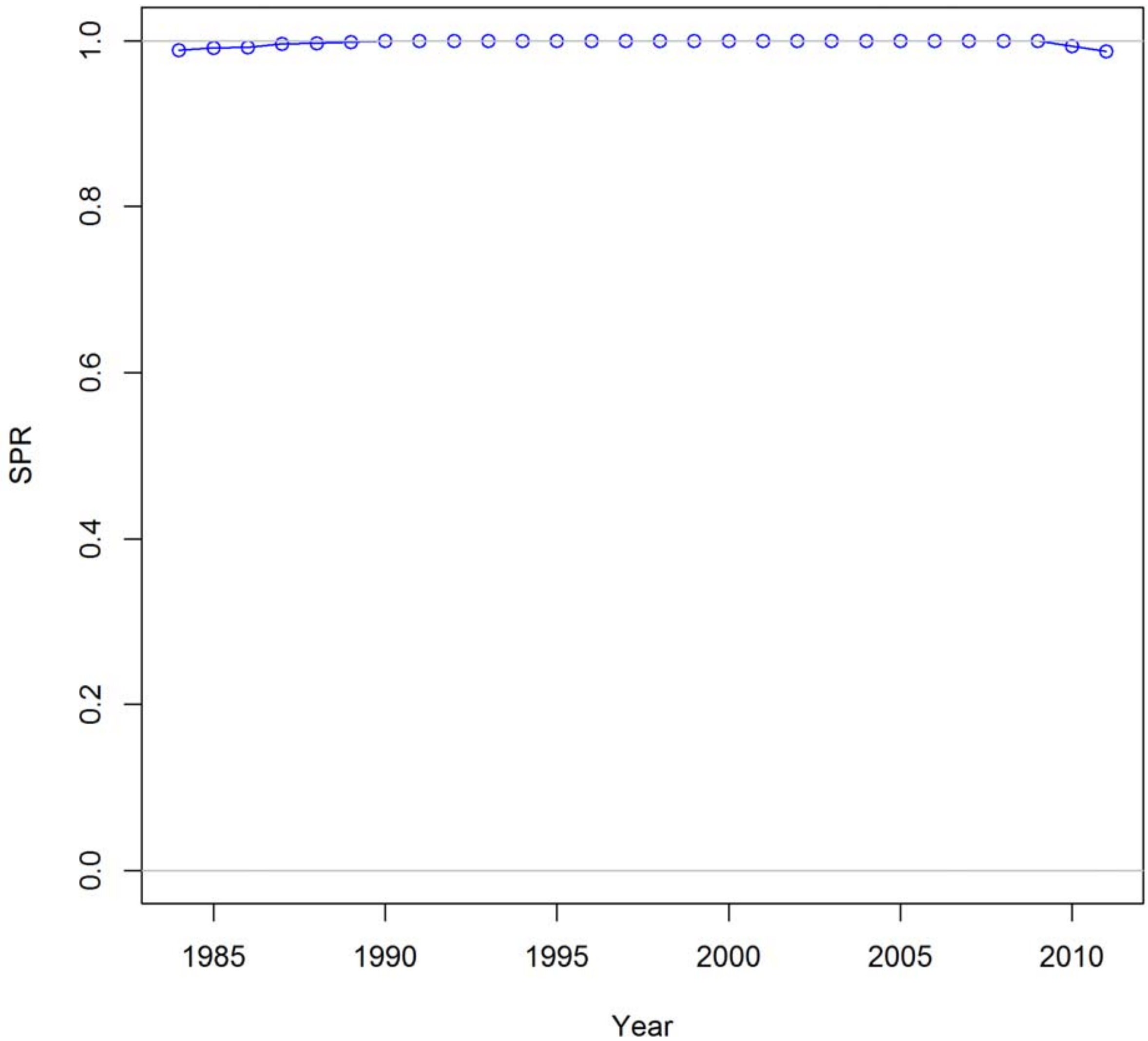

Ending year selectivity and growth for Fishery
Length (cm)
Age (yr)
20
15
10
5
0
5
10
15
20
25
30
1
1
0.8
0.6
0.4
0.2

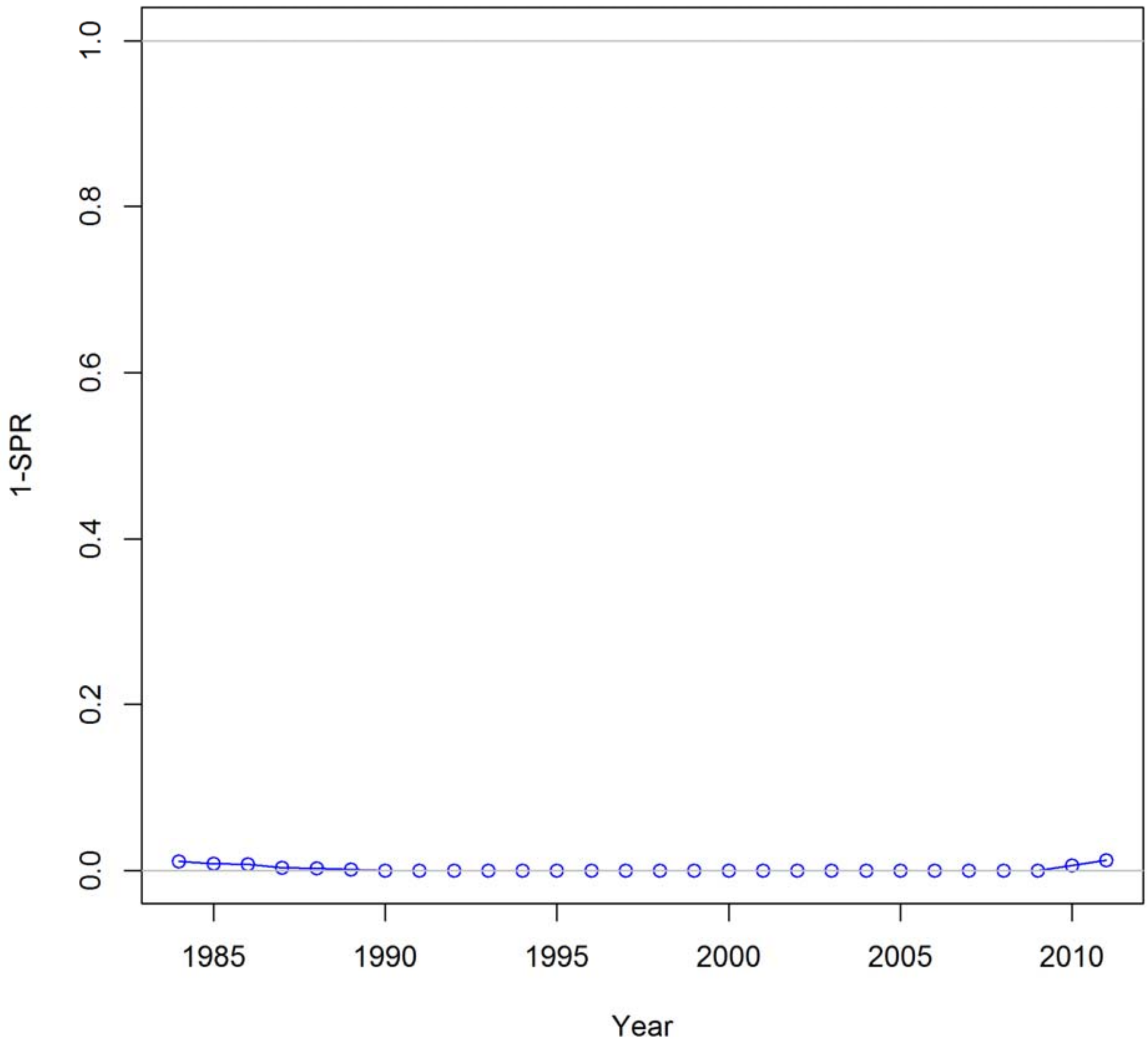


Ending year selectivity and growth for NperTow+mm
Length (cm)
Age (yr)
0.4
0.6
0.8
0.8
0.6
0.4
0.2
20
15
10
5
0
5
10
15
20
25
30

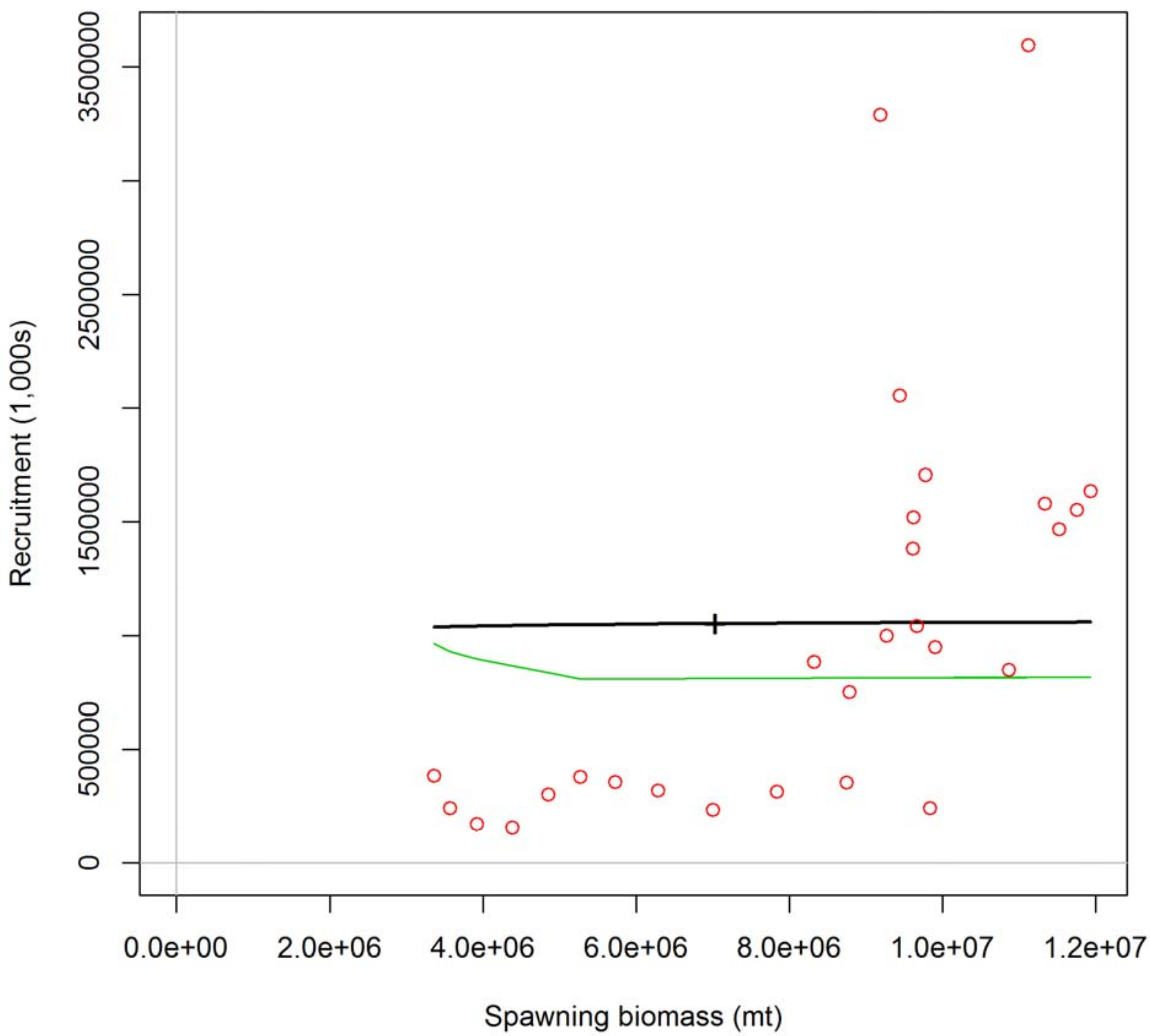


Ending year selectivity and growth for SWAN
Length (cm)
Age (yr)
0
5
10
15
20
25
30
5
10
15
20
0.4
0.6
0.8
0.8
0.6
0.4
0.2

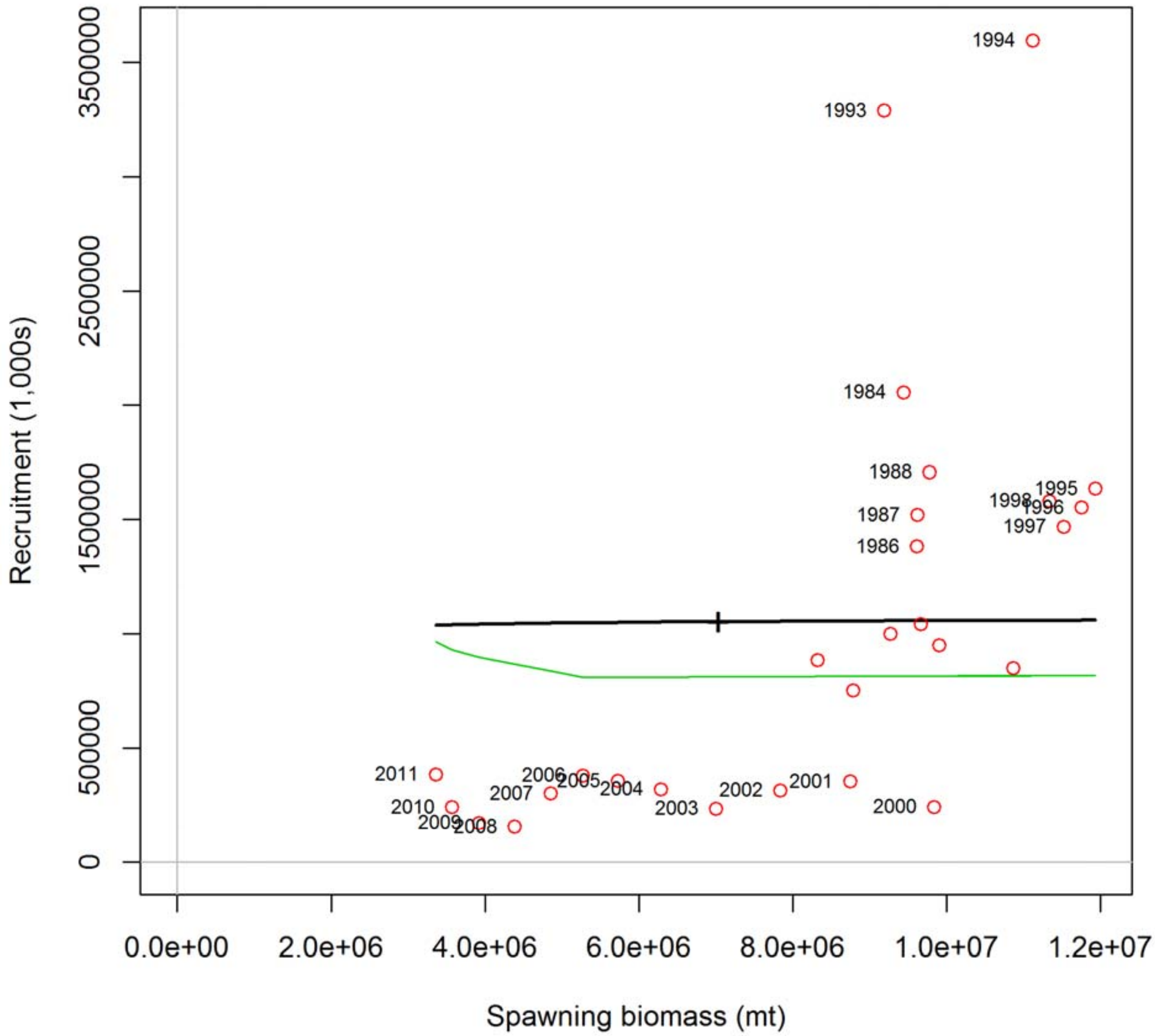

1.0
0.8
0.6
0.4
0.2
0.0
SPR
1985
1990
1995
2000
2005
2010
Year



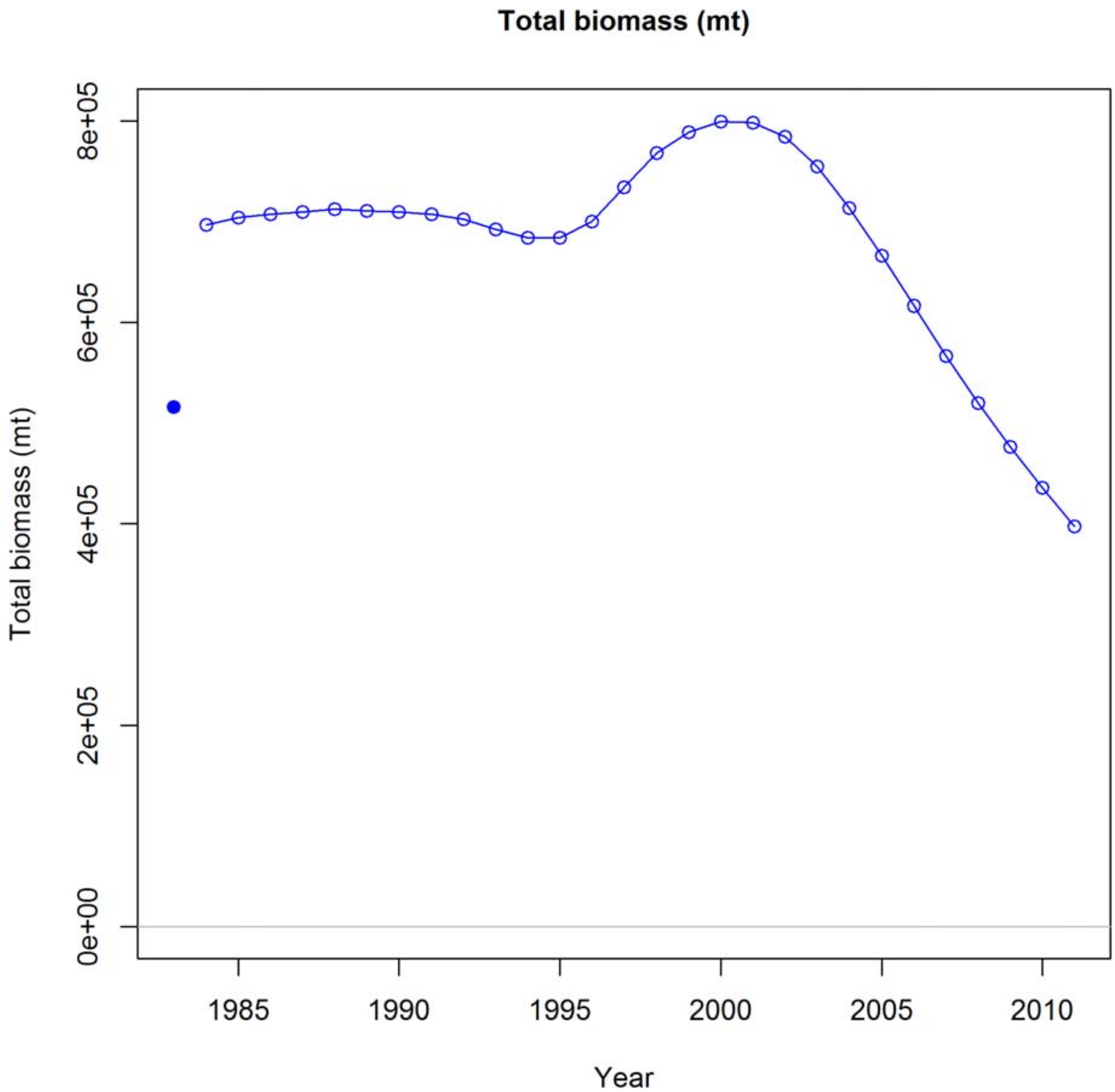
1-SPR
0.0
0.2
0.4
0.6
0.8
1.0
1985
1990
1995
2000
2005
2010
Year

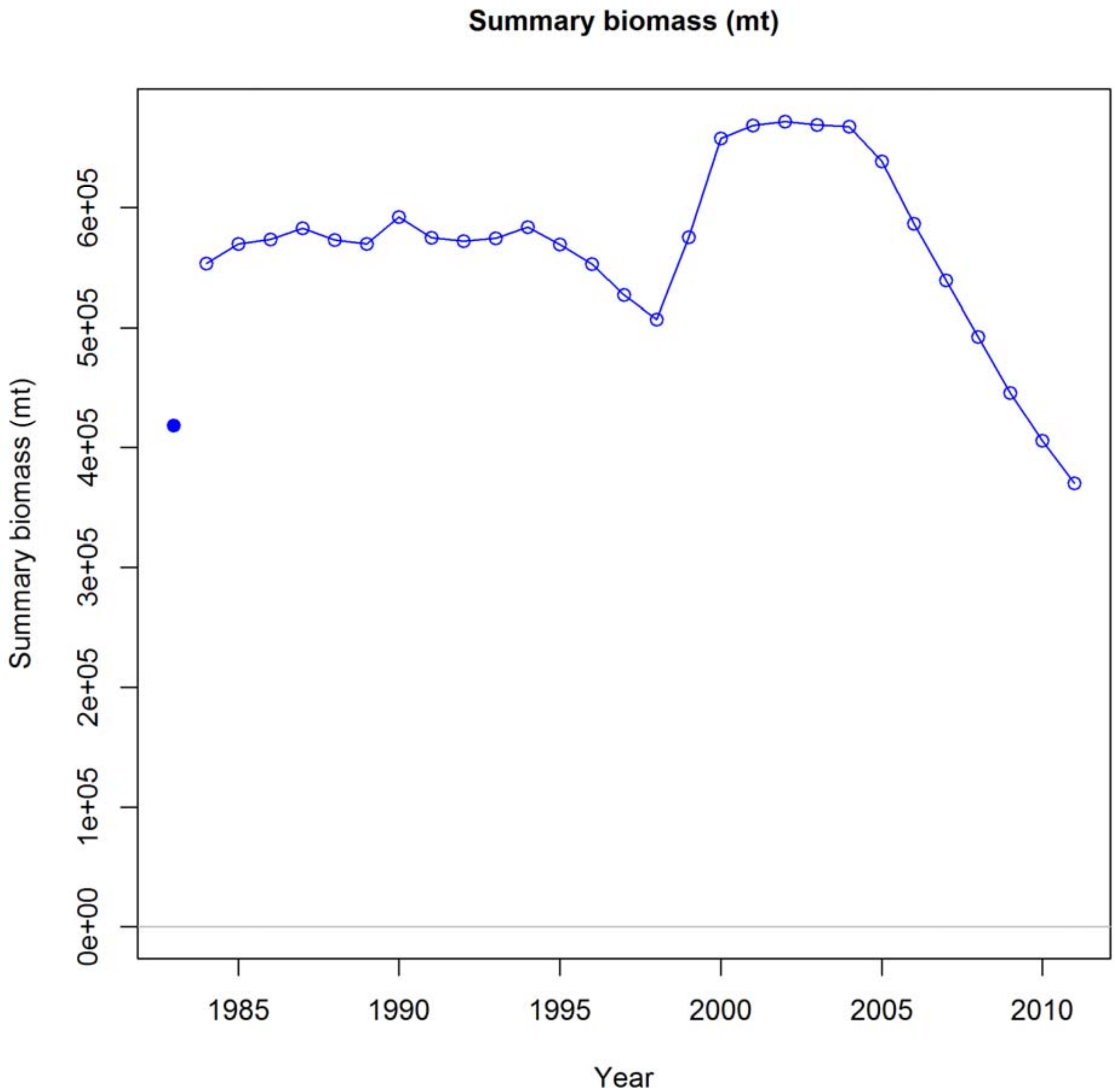


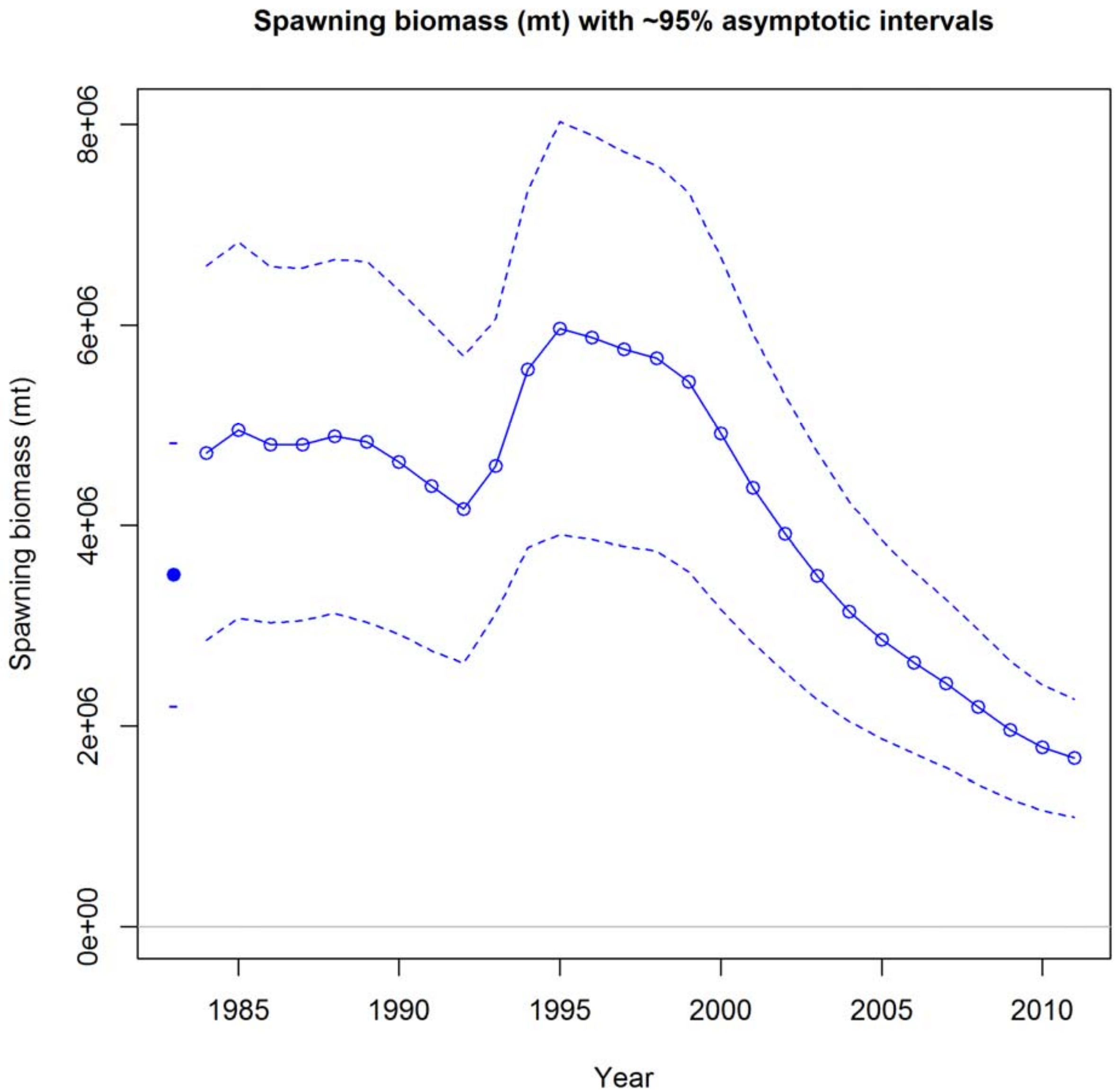
Recruitment (1,000s)
0
500000
1500000
2500000
3500000
0.0e+00
2.0e+06
4.0e+06
6.0e+06
8.0e+06
1.0e+07
1.2e+07
Spawning biomass (mt)

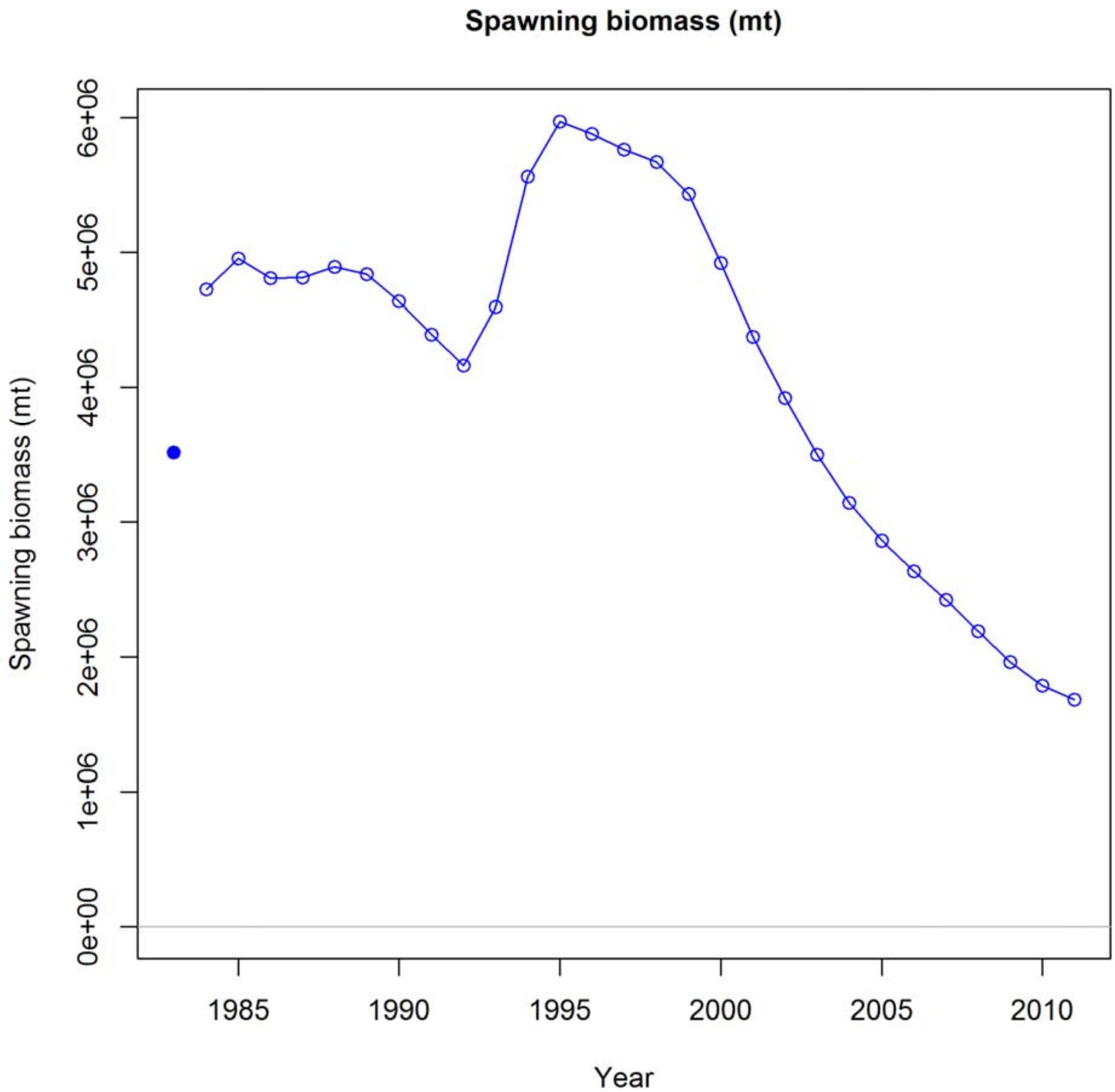


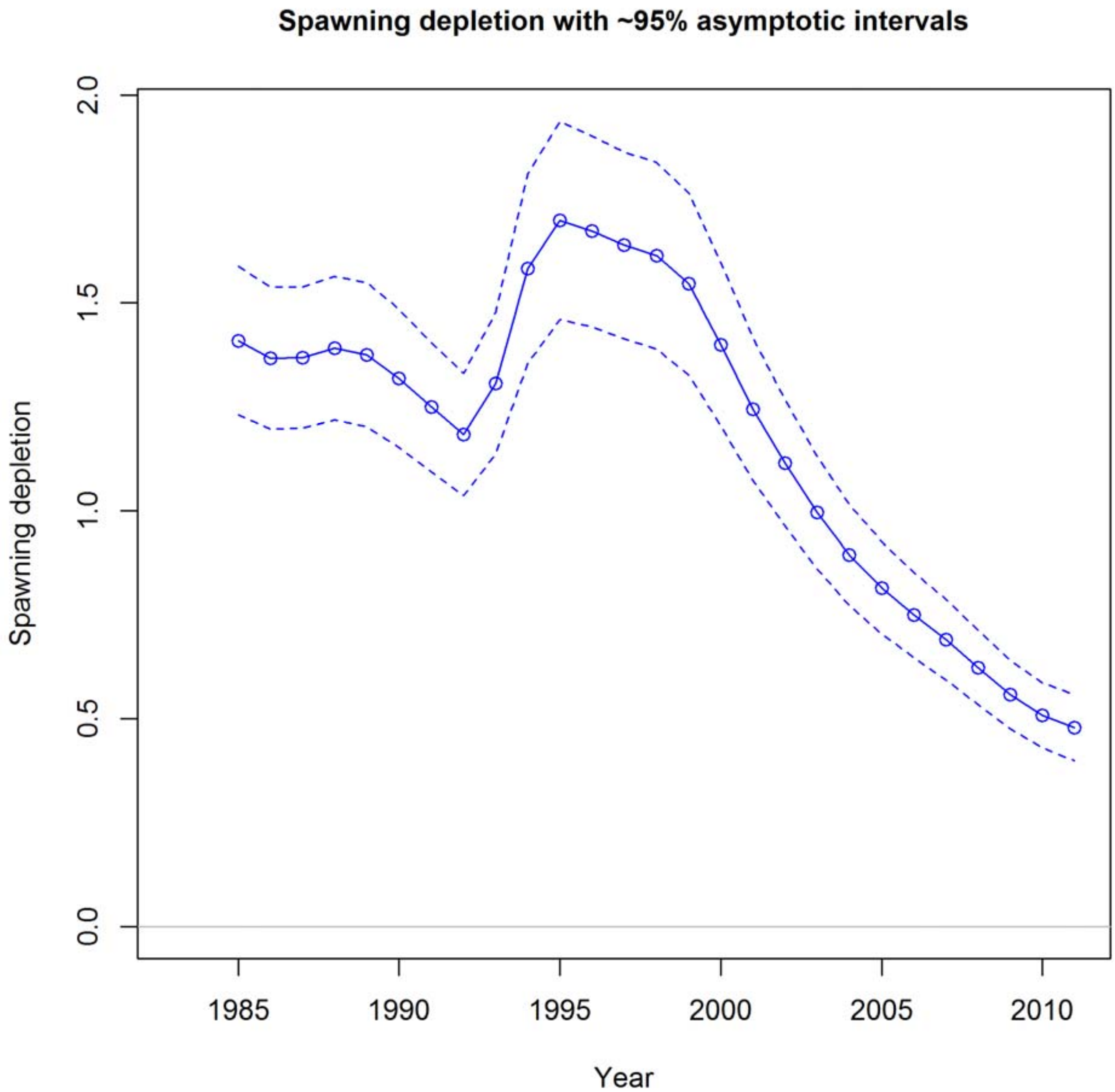
Recruitment (1,000s)
Spawning biomass (mt)
0
500000
1500000
2500000
3500000
0.0e+00
2.0e+06
4.0e+06
6.0e+06
8.0e+06
1.0e+07
1.2e+07
1994
1993
1984
1988
1987
1986
1995
1998
1996
1997
2011
2006
2005
2004
2007
2010
2009
2008
2003
2002
2001
2000


Total biomass (mt)
8e+05
6e+05
4e+05
2e+05
0e+00
Total biomass (mt)
1985
1990
1995
2000
2005
2010
Year

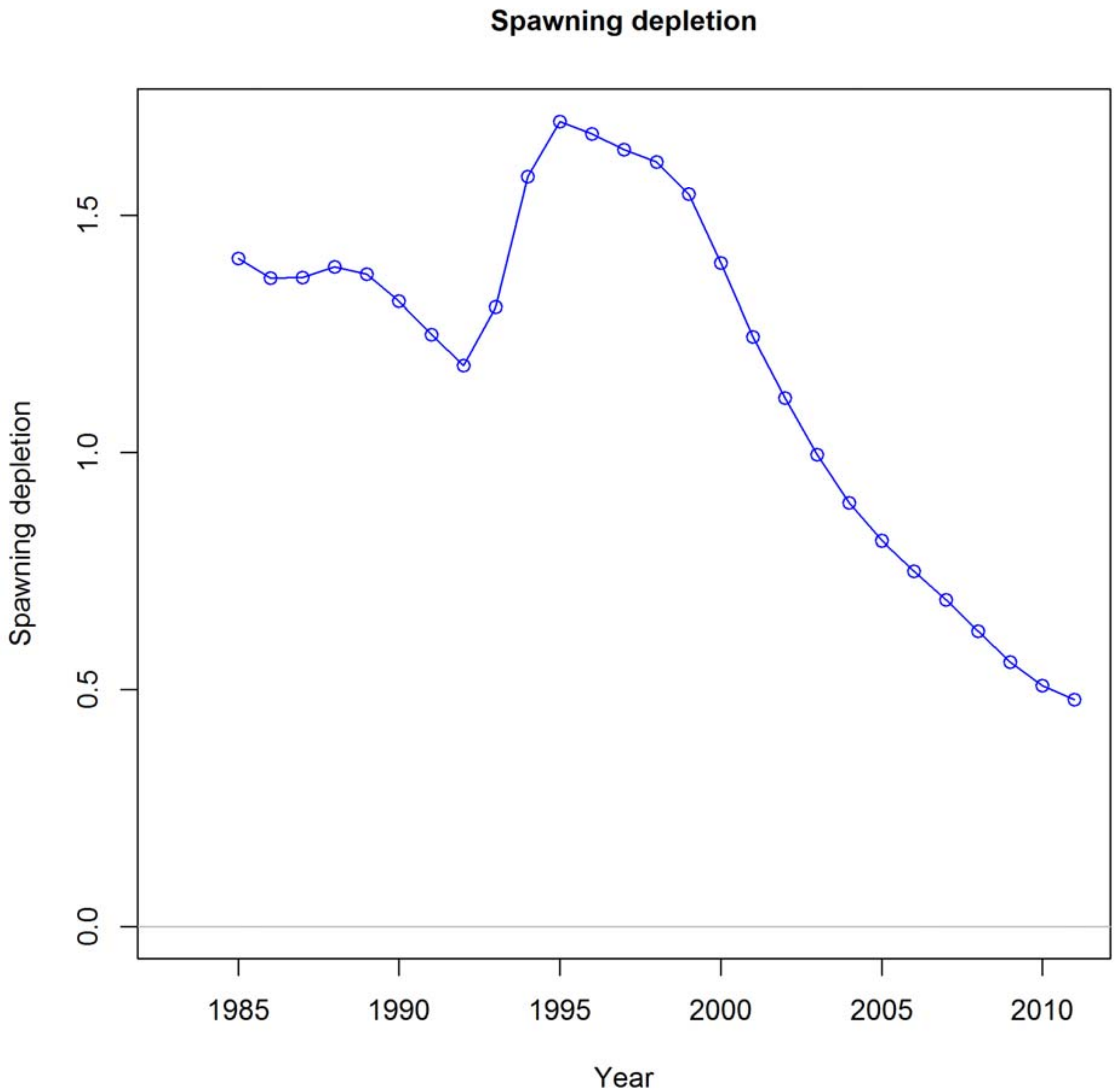

Summary biomass (mt)
Summary biomass (mt)
0e+00
1e+05
2e+05
3e+05
4e+05
5e+05
6e+05
1985
1990
1995
2000
2005
2010
Year

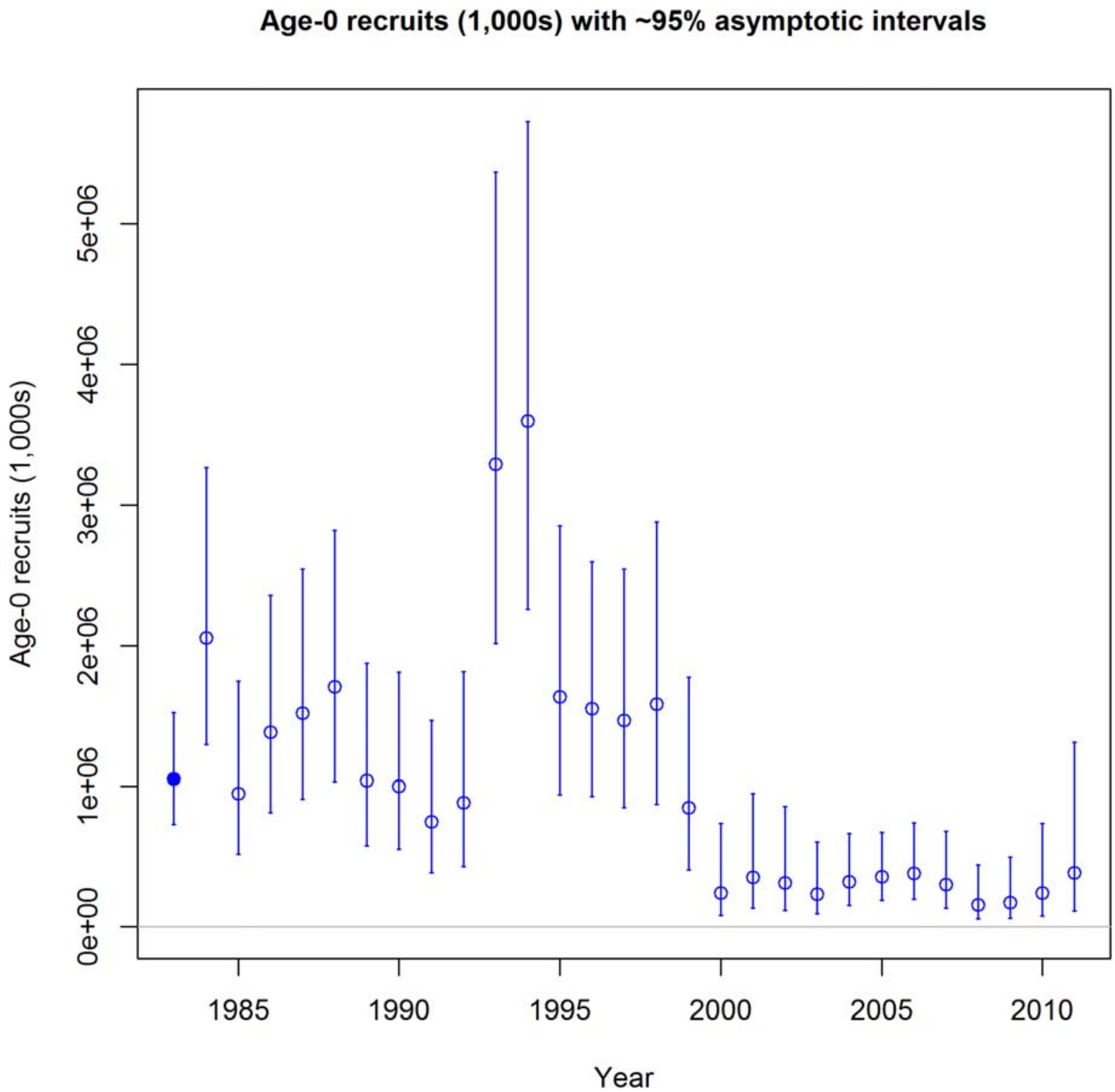

Spawning biomass (mt) with ~95% asymptotic intervals
Spawning biomass (mt)
0e+00
2e+06
4e+06
6e+06
8e+06
1985
1990
1995
2000
2005
2010
Year

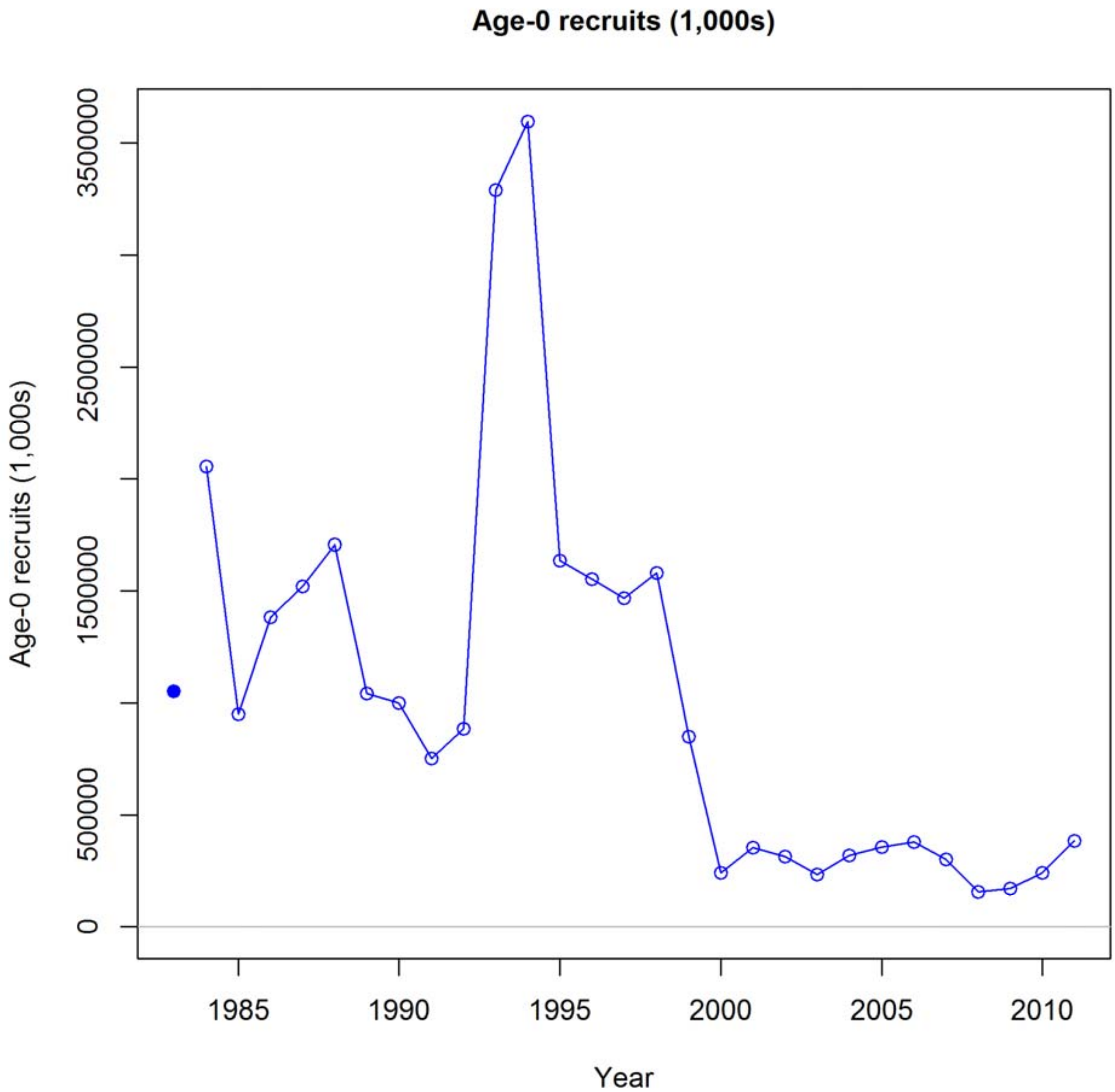

Spawning biomass (mt)
0e+00
1e+06
2e+06
3e+06
4e+06
5e+06
6e+06
Spawning biomass (mt)
1985
1990
1995
2000
2005
2010
Year

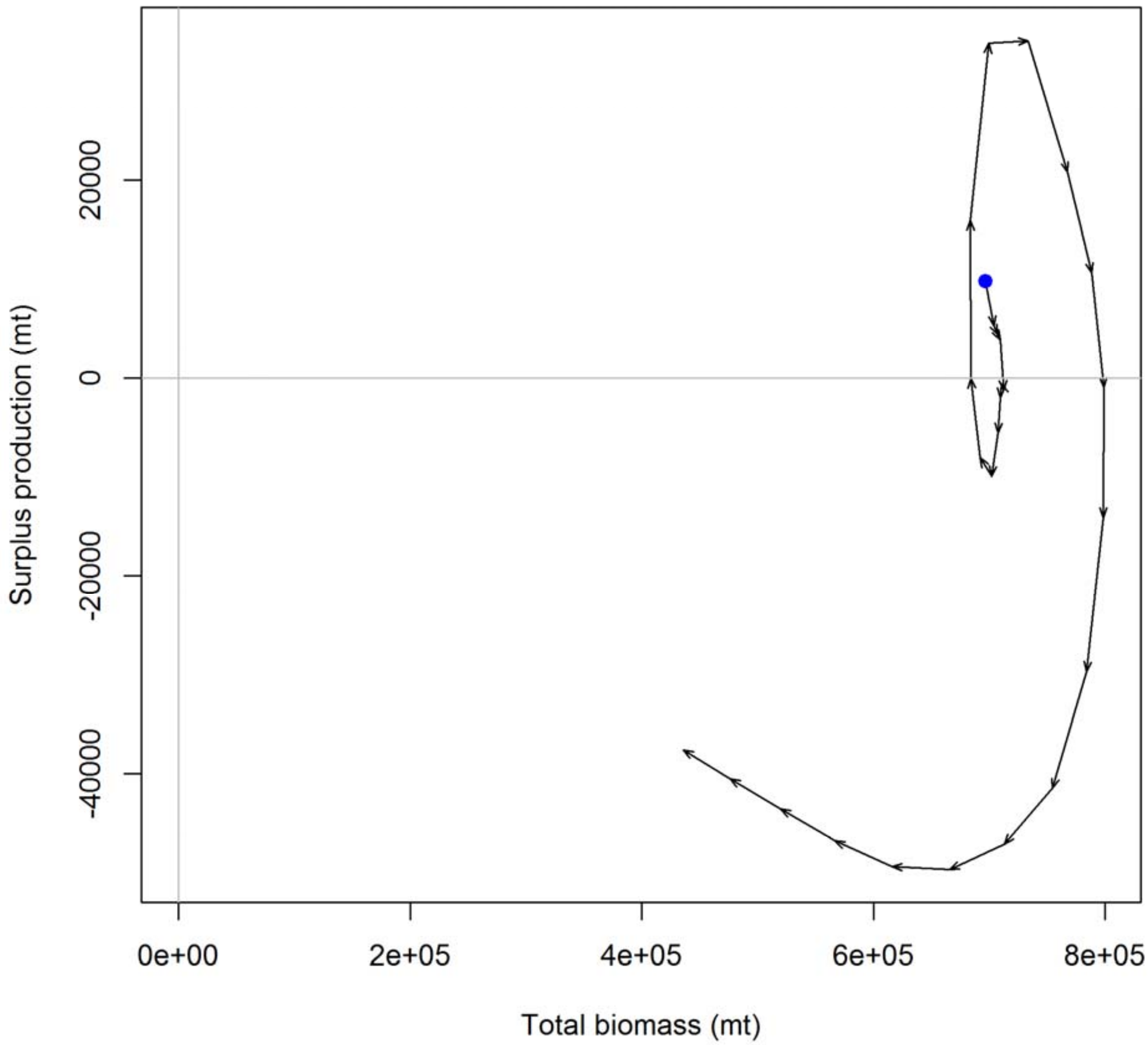


Spawning depletion with ~95% asymptotic intervals
Spawning depletion
Year
0.0
0.5
1.0
1.5
2.0
1985
1990
1995
2000
2005
2010


Spawning depletion
Spawning depletion
0.0
0.5
1.0
1.5
1985
1990
1995
2000
2005
2010
Year


Age-0 recruits (1,000s) with ~95% asymptotic intervals
Age-0 recruits (1,000s)
0e+00
1e+06
2e+06
3e+06
4e+06
5e+06
1985
1990
1995
2000
2005
2010
Year


Age-0 recruits (1,000s)
Age-0 recruits (1,000s)
0
500000
1500000
2500000
3500000
1985
1990
1995
2000
2005
2010
Year



Surplus production (mt)
20000
0
-20000
-40000
0e+00
2e+05
4e+05
6e+05
8e+05
Total biomass (mt)

Appendix A8: Swept area biomass analysis

Efficiency corrected swept-area biomass

Efficiency corrected swept area biomass and catch/biomass fishing mortality estimates have been used in past assessments to provide management advice. Although they no longer serve that purpose, they are still used to estimate scale in KLAMZ modeling.

Efficiency corrected swept area biomass and catch/biomass fishing mortality estimates were calculated with CVs for surfclams during 1997-2011 (years with dredge performance sensors deployed on surveys) on a regional basis, using the methods described in NEFSC (2010) (Table 1-2 and Figures 1-2).

Efficiency corrected swept-area biomass and fishing mortality estimates in this assessment for years prior to 2011 differ from estimates in previous assessments due to: 1) changes after the 2011 survey in the criteria used to judge a “bad” (with poor gear performance) survey tow; 2) the availability of data for 2011 that could be borrowed to help fill “holes” (unsampled strata) in the survey data for 2008; 3) new shell length meat weight relationships; 4) the updated estimate of survey dredge capture efficiency; and 5) use of a new survey dredge selectivity curve to calculate stock biomass.

A historical retrospective analysis was carried out to demonstrate the stability of efficiency corrected swept area biomass estimates. Swept-area biomass and fishing mortality calculations have changed from assessment to assessment as additional survey data accumulated and, mainly, as estimates of survey dredge efficiency were refined (Table 3, Figure 3).

Working group members were interested in seeing the ratio of swept area biomasses by region (Figure 4).

Appendix A8. Table 1. Efficiency corrected swept-area biomass estimates (1000 mt) and CVs for surfclams (120+ mm SL), by region.

	Estimate	CV
INPUT: Nominal tow distance (dn, nm)	0.15	
INPUT: Dredge width (nm)	0.00082	
Area swept per standard tow (a, nm2)	0.00012	10%

Area of assessment region (A, nm2) - no correction for stations with unsuitable clam habitat

	Estimate	CV
S. Virginia and N. Carolina (SVA)	3,119	10%
Delmarva (DMV)	4,660	10%
New Jersey (NJ)	5,078	10%
Long Island (LI)	2,917	10%
Southern New England (SNE)	4,321	10%
Georges Bank (GBK)	5,772	10%
Total	25,867	

INPUT: Fraction suitable habitat (u)

	Estimate	CV
S. Virginia and N. Carolina (SVA)	100%	10%
Delmarva (DMV)	100%	10%
New Jersey (NJ)	100%	10%
Long Island (LI)	100%	10%
Southern New England (SNE)	100%	10%
Georges Bank (GBK)	88%	10%

Habitat area in assessment region (A', nm2)

	Estimate	CV
S. Virginia and N. Carolina (SVA)	3,119	14%
Delmarva (DMV)	4,660	14%
New Jersey (NJ)	5,078	14%
Long Island (LI)	2,917	14%
Southern New England (SNE)	4,321	14%
Georges Bank (GBK)	5,079	14%

INPUT: Biomass fraction in unsurveyd deep water

	Estimate	CV
S. Virginia and N. Carolina (SVA)	0%	10%
Delmarva (DMV)	0%	10%
New Jersey (NJ)	0%	10%
Long Island (LI)	0%	10%
Southern New England (SNE)	0%	10%
Georges Bank (GBK)	0%	10%

INPUT: Original survey mean catch from fishable stock (kg/tow, for tows adjusted to nominal tow distance using sensors)

	Estimates	CV	Estimates	CV	Estimates	CV	Estimates	CV	Estimates	CV	Estimates	CV
S. Virginia and N. Carolina (SVA) 120+ mm	0.0230	42%	0.0887	42%	0.4486	59%	0.0000	0%	0.0030	100%	0.0065	100%
Delmarva (DMV) 120+ mm	2.4641	19%	1.3336	18%	2.5392	20%	0.7967	16%	0.4146	34%	0.8732	43%
New Jersey (NJ) 120+ mm	6.3488	11%	4.5417	17%	3.8543	14%	2.3883	11%	3.9031	17%	1.8693	23%
Long Island (LI) 120+ mm	0.3672	66%	0.9268	51%	0.2407	64%	2.2825	36%	0.4535	24%	1.2362	35%
Southern New England (SNE) 120+ mm	1.4769	34%	0.8400	66%	0.6545	24%	0.6508	43%	1.2236	47%	0.2323	27%
Georges Bank (GBK) 120+ mm	2.0151	21%	2.4106	32%	2.2545	43%	3.9404	23%	4.3871	21%	3.8483	25%

Swept-area biomass without efficiency correction (B', 1000 mt):

	Estimates	CV	Estimates	CV	Estimates	CV	Estimates	CV	Estimates	CV	Estimates	CV
S. Virginia and N. Carolina (SVA) 120+ mm	0.5817	47%	2.2433	47%	11.3402	63%	0.0000	20%	0.0753	102%	0.1641	102%
Delmarva (DMV) 120+ mm	93.0714	28%	50.3714	27%	95.9086	28%	30.0930	26%	15.6612	39%	32.9812	47%
New Jersey (NJ) 120+ mm	261.3123	23%	186.9338	26%	158.6390	24%	98.2987	23%	160.6465	26%	76.9379	31%
Long Island (LI) 120+ mm	8.6828	69%	21.9131	55%	5.6915	67%	53.9670	41%	10.7226	32%	29.2277	40%
Southern New England (SNE) 120+ mm	51.7246	39%	29.4211	69%	22.9215	31%	22.7916	47%	42.8541	51%	8.1361	34%
Georges Bank (GBK) 120+ mm	82.9608	29%	99.2444	38%	92.8198	47%	162.2261	31%	180.6177	29%	158.4357	32%
SVA to SNE	415	17%	291	19%	295	16%	205	17%	230	21%	147	21%
Total (including GBK)	498	15%	390	17%	387	17%	367	17%	411	17%	306	19%
INPUT: Survey dredge efficiency (e) from Patch mo	0.234	132%	0.234	132%	0.234	132%	0.234	132%	0.234	132%	0.234	132%

Efficiency adjusted swept area fishable biomass (B, 1000 mt)

	Estimates	CV	Estimates	CV	Estimates	CV	Estimates	CV	Estimates	CV	Estimates	CV
S. Virginia and N. Carolina (SVA) 120+ mm	2.486	140%	9.587	140%	48.463	146%	0.000	134%	0.322	167%	0.701	167%
Delmarva (DMV) 120+ mm	398	135%	215	135%	410	135%	129	134%	67	138%	141	140%
New Jersey (NJ) 120+ mm	1,117	134%	799	135%	678	134%	420	134%	687	135%	329	136%
Long Island (LI) 120+ mm	37	149%	94	143%	24	148%	231	138%	46	136%	125	138%
Southern New England (SNE) 120+ mm	221	138%	126	149%	98	136%	97	140%	183	141%	35	136%
Georges Bank (GBK) 120+ mm	355	135%	424	137%	397	140%	693	136%	772	135%	677	136%
SVA to SNE	1,775	133%	1,243	133%	1,259	133%	877	133%	983	134%	630	134%
Total (including GBK)	2,130	133%	1,667	133%	1,655	133%	1,570	133%	1,755	133%	1,307	133%

Lower bound for 80% confidence intervals on fishable biomass (1000 mt, for lognormal distribution with no bias correction)

	Estimates	Estimates	Estimates	Estimates	Estimates	Estimates
S. Virginia and N. Carolina (SVA) 120+ mm	0.655	2.526	12.338		0.074	0.160
Delmarva (DMV) 120+ mm	108	59	111	35	18	37
New Jersey (NJ) 120+ mm	305	217	185	115	187	89
Long Island (LI) 120+ mm	9	24	6	61	12	33
Southern New England (SNE) 120+ mm	59	32	26	26	48	9
Georges Bank (GBK) 120+ mm	96	114	104	188	209	183
SVA to SNE	488	341	346	241	269	172
Total (including GBK)	586	458	455	431	482	358

Upperbound for 80% confidence intervals on fishable biomass (1000 mt, for lognormal distribution with no bias correction)

S. Virginia and N. Carolina (SVA) 120+ mm	9.433	36.381	190.363		1.409	3.070
Delmarva (DMV) 120+ mm	1,464	792	1,509	472	251	535
New Jersey (NJ) 120+ mm	4,089	2,936	2,485	1,538	2,522	1,215
Long Island (LI) 120+ mm	148	362	97	866	170	468
Southern New England (SNE) 120+ mm	827	502	362	370	700	129
Georges Bank (GBK) 120+ mm	1,308	1,584	1,507	2,562	2,847	2,505
SVA to SNE	6,461	4,535	4,580	3,192	3,590	2,302
Total (including GBK)	7,741	6,072	6,026	5,715	6,391	4,769

Appendix A8.Table 2. Fishing mortality estimates for surfclams based on catch and efficiency corrected swept area biomass estimates.

INPUT: Incidental mortality allowance	12%
INPUT: Assumed CV for catch	10%

INPUT: Landings (1000 mt, discard ~ 0)	Estimates for 1997	Estimates for 1999	Estimates for 2002	Estimates for 2005	Estimates for 2008	Estimates for 2011
S. Virginia and N. Carolina (SVA)	0.000	0.000	0.064	0.000	0.000	0.000
Delmarva (DMV)	1.540	0.648	4.489	1.668	3.223	1.427
New Jersey (NJ)	16.998	18.749	18.271	16.850	17.517	11.908
Long Island (LI)	0.073	0.157	1.130	0.759	1.317	0.437
Southern New England (SNE)	0.000	0.016	0.052	1.885	0.423	2.420
Georges Bank (GBK)	0.000	0.000	0.000	0.000	0.000	2.397
Total	18.611	19.570	24.006	21.163	22.481	18.589

Catch (1000 mt, landings + upper bound incidental mortality allowance)						
S. Virginia and N. Carolina (SVA)	0.000	0.000	0.072	0.000	0.000	0.000
Delmarva (DMV)	1.725	0.726	5.028	1.868	3.610	1.598
New Jersey (NJ)	19.038	20.999	20.463	18.872	19.619	13.337
Long Island (LI)	0.081	0.176	1.265	0.850	1.475	0.489
Southern New England (SNE)	0.000	0.018	0.058	2.112	0.474	2.710
Georges Bank (GBK)	0.000	0.000	0.000	0.000	0.000	2.685
Total	20.844	21.919	26.886	23.702	25.178	20.820

INPUT: Efficiency Corrected Swept Area Biomass for Fishable Stock (1000 mt)	Estimates for 1997	CV	Estimates for 1999	CV	Estimates for 2002	CV	Estimates for 2005	CV	Estimates for 2008	CV	Estimates for 2011	CV
S. Virginia and N. Carolina (SVA) 120+ mm	2	140%	10	140%	48	146%	0	134%	0	167%	1	167%
Delmarva (DMV) 120+ mm	398	135%	215	135%	410	135%	129	134%	67	138%	141	140%
New Jersey (NJ) 120+ mm	1,117	134%	799	135%	678	134%	420	134%	687	135%	329	136%
Long Island (LI) 120+ mm	37	149%	94	143%	24	148%	231	138%	46	136%	125	138%
Southern New England (SNE) 120+ mm	221	138%	126	149%	98	136%	97	140%	183	141%	35	136%
Georges Bank (GBK) 120+ mm	355	135%	424	137%	397	140%	693	136%	772	135%	677	136%
SVA to SNE	1,775	133%	1,243	133%	1,259	133%	877	133%	983	134%	630	134%
Total (including GBK)	2,130	133%	1,667	133%	1,655	133%	1,570	133%	1,755	133%	1,307	133%

Fishing mortality (y^{-1})												
S. Virginia and N. Carolina (SVA) 120+ mm	0.0000	NA	0.0000	NA	0.0015	146%	0.0000	NA	0.0000	NA	0.0000	NA
Delmarva (DMV) 120+ mm	0.0043	135%	0.0034	135%	0.0123	135%	0.0145	135%	0.0539	138%	0.0113	141%
New Jersey (NJ) 120+ mm	0.0170	134%	0.0263	135%	0.0302	135%	0.0449	134%	0.0286	135%	0.0406	136%
Long Island (LI) 120+ mm	0.0022	149%	0.0019	143%	0.0520	148%	0.0037	139%	0.0322	136%	0.0039	138%
Southern New England (SNE) 120+ mm	0.0000	138%	0.0001	149%	0.0006	136%	0.0217	141%	0.0026	142%	0.0780	137%
Georges Bank (GBK) 120+ mm	0.0000	NA	0.0000	NA	0.0000	NA	0.0000	NA	0.0000	NA	0.0040	136%
SVA to SNE	0.0117	133%	0.0176	134%	0.0214	133%	0.0270	133%	0.0256	134%	0.0400	134%
Total (including GBK)	0.0098	133%	0.0131	134%	0.0162	133%	0.0151	133%	0.0143	134%	0.0193	134%

Lower bound for 80% confidence intervals for fishing mortality (y^{-1}, for lognormal distribution with no bias correction)	Estimates for 1997	Estimates for 1999	Estimates for 2002	Estimates for 2005	Estimates for 2008	Estimates for 2011
S. Virginia and N. Carolina (SVA) 120+ mm	NA	NA	0.0004	NA	NA	NA
Delmarva (DMV) 120+ mm	0.0012	0.0009	0.0033	0.0039	0.0144	0.0030
New Jersey (NJ) 120+ mm	0.0046	0.0071	0.0082	0.0122	0.0078	0.0110
Long Island (LI) 120+ mm	0.0005	0.0005	0.0131	0.0010	0.0087	0.0010
Southern New England (SNE) 120+ mm	NA	0.0000	0.0002	0.0057	0.0007	0.0210
Georges Bank (GBK) 120+ mm	NA	NA	NA	NA	NA	0.0011
SVA to SNE	0.0032	0.0048	0.0059	0.0074	299.3489	0.0070
Total (including GBK)	0.0027	0.0036	0.0045	0.0041	628.5781	0.0039

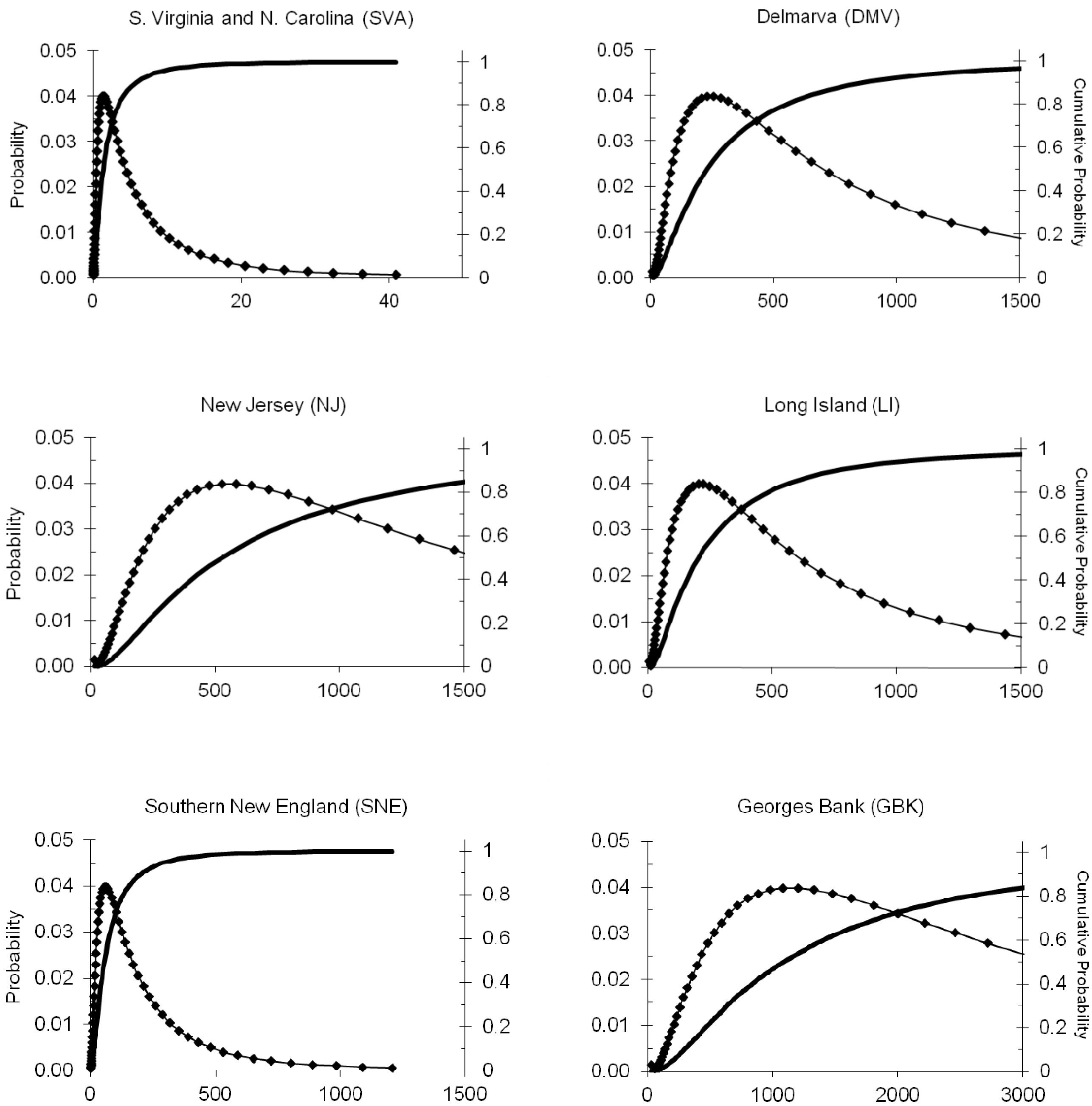
Upper bound for 80% confidence intervals for fishing mortality (y^{-1}, for lognormal distribution with no bias correction)						
S. Virginia and N. Carolina (SVA) 120+ mm	NA	NA	0.0059	NA	NA	NA
Delmarva (DMV) 120+ mm	0.0160	0.0124	0.0453	0.0535	0.2024	0.0091
New Jersey (NJ) 120+ mm	0.0626	0.0968	0.1109	0.1648	0.1052	0.0458
Long Island (LI) 120+ mm	0.0088	0.0073	0.2069	0.0139	0.1194	0.0023
Southern New England (SNE) 120+ mm	NA	0.0006	0.0022	0.0825	0.0099	0.1090
Georges Bank (GBK) 120+ mm	NA	NA	NA	NA	NA	NA
SVA to SNE	0.0428	0.0645	0.0779	0.0986	0.0938	0.0447
Total (including GBK)	0.0357	0.0480	0.0593	0.0551	0.0524	0.0175

Appendix A8. Table 3. Historical retrospective analysis of efficiency corrected swept area biomass estimates.

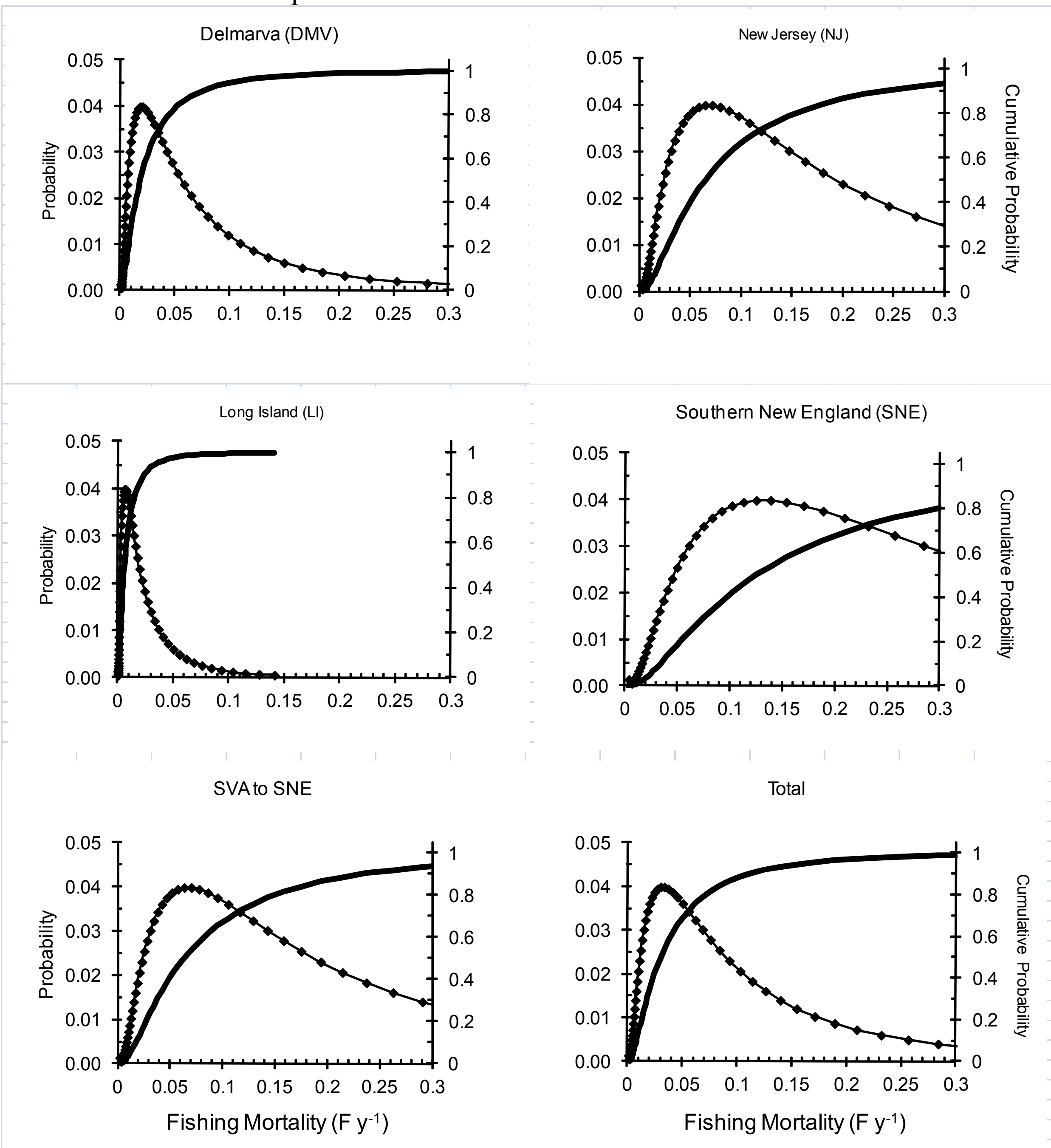
Sizes	SARC-26 All		SARC-30 All		SARC-37 110+ and 120+		SARC-44 120+ mm		SARC-49 120+ mm		New assessment 120+ mm	
Year	Biomass (1000 mt)	Survey efficiency (e)	Biomass (1000 mt)	Survey efficiency (e)	Biomass (1000 mt)	Survey efficiency (e)	Biomass (1000 mt)	Survey efficiency (e)	Biomass (1000 mt)	Survey efficiency (e)	Biomass (1000 mt)	Survey efficiency (e)
1997	1,130	0.897	1,106	0.588	1,146	0.460	1,913	0.226	1,276	0.372	2,130	0.234
1999			1,596	0.276	1,460	0.276	1,503	0.226	1,005	0.372	1,667	0.234
2002					803	0.389	1,479	0.226	1,082	0.372	1,655	0.234
2005							1,066	0.226	954	0.256	1,570	0.234
2008									1,038	0.372	1,755	0.256
2011											1,307	0.234

Sizes	SARC-26 All		SARC-30 All		SARC-37 110+ and 120+		SARC-44 120+ mm		SARC-49 120+ mm		New assessment 120+ mm	
Year	Fishing mortality	Survey efficiency (e)	Fishing mortality	Survey efficiency (e)	Fishing mortality	Survey efficiency (e)	Fishing mortality	Survey efficiency (e)	Fishing mortality	Survey efficiency (e)	Fishing mortality	Survey efficiency (e)
1997	0.0181	0.897	0.0188	0.588	0.0180	0.460	0.0109	0.226	0.0163	0.372	0.0098	0.234
1999			0.0137	0.276	0.0150	0.276	0.0146	0.226	0.0218	0.372	0.0131	0.234
2002					0.0330	0.389	0.0182	0.226	0.0248	0.372	0.0162	0.234
2005							0.0222	0.226	0.0248	0.372	0.0151	0.234
2008									0.0243	0.372	0.0143	0.234
2011											0.0193	0.234

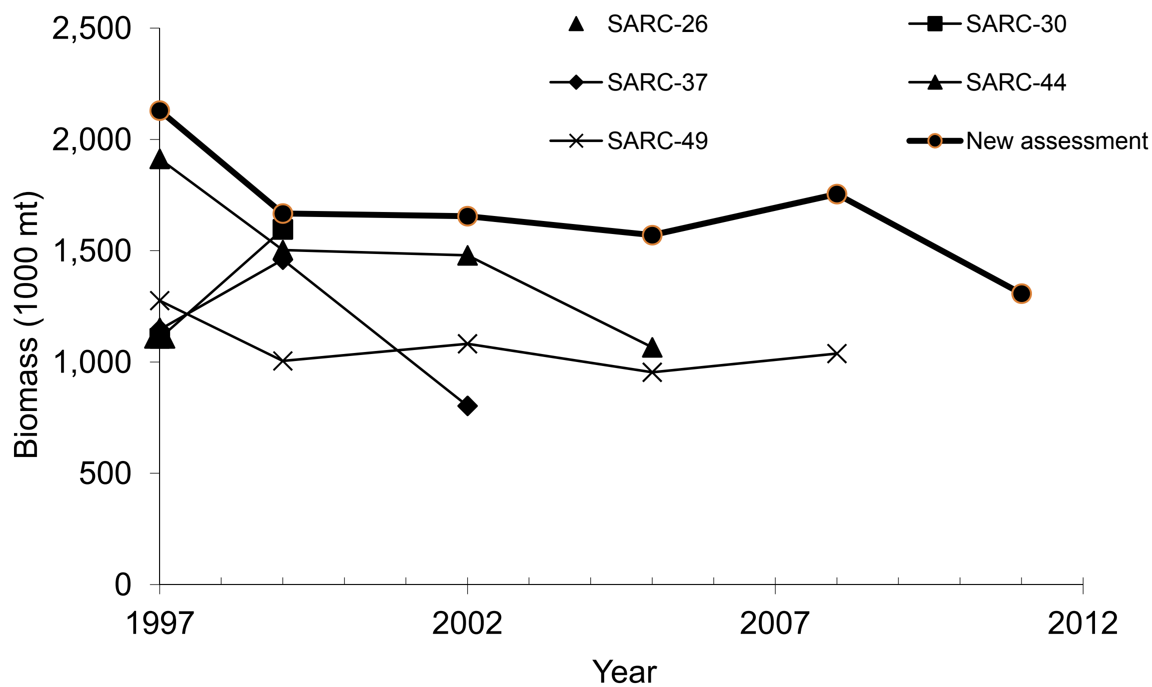
Appendix A8. Figure 1. Uncertainty in efficiency corrected swept area biomass estimates for surfclams in 2011. Note that the x-axis differs in the panel for SVA and GBK but is the same in other panels to facilitate comparisons.

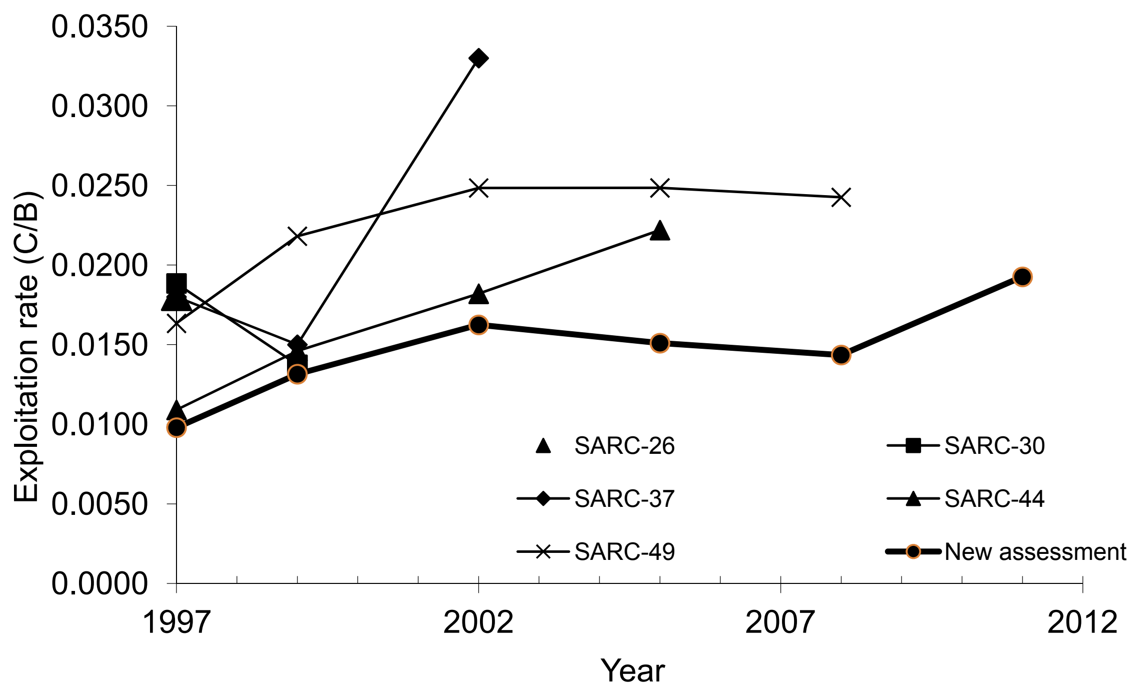


Appendix A8. Figure 2. Uncertainty in fishing mortality estimates for surfclams during 2011 based on catch data and efficiency corrected swept-area biomass. X-axes are scaled to the same maximum to facilitate comparisons.

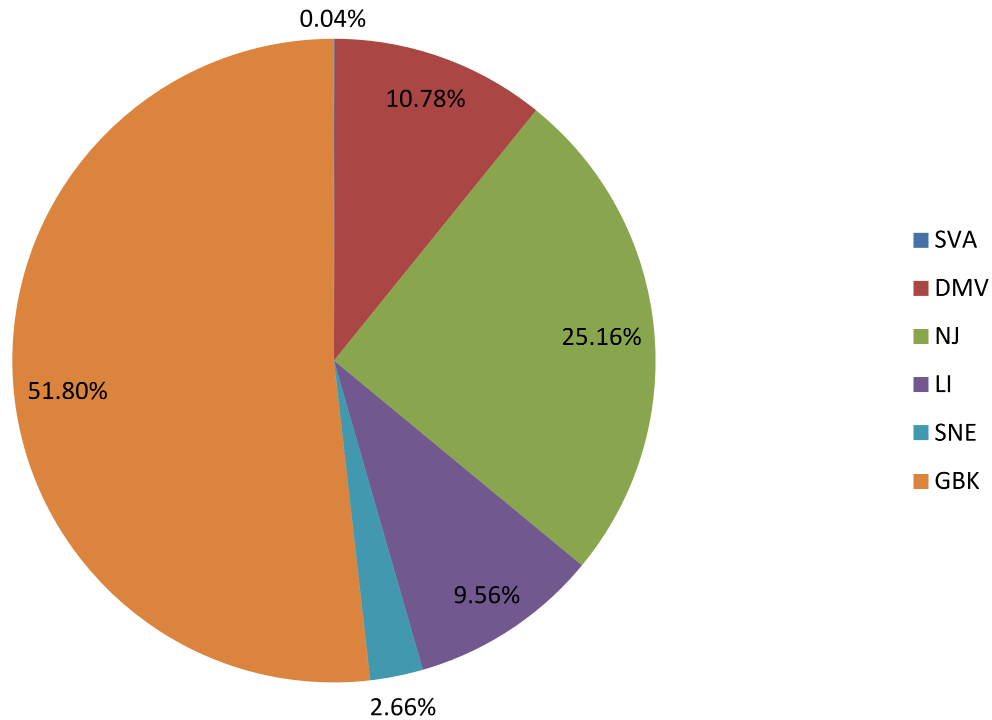


Appendix A8. Figure 3. Historical retrospective analysis of efficiency corrected swept area biomass and exploitation rate (catch / biomass).





Appendix A8. Figure 4. Percentage of total swept area biomass by region in 2011.



Appendix A9. Additional Sensitivity Testing and Decision Table Analyses

Uncertainty in estimating the scale of biomass has been a challenge in surfclam assessments for many years. We carried out additional sensitivity analyses to determine the likely effects of potential management actions (catch levels) if the biomass scale estimated in the basecase model is substantially too high or too low. The biomass reference points used in this assessment mitigate the scale problem to some degree because the calculation used to determine biomass status B2011/(B1999/4) is robust and does not change appreciably if the overall scale estimated by the assessment model changes, as long as trend can be estimated with relative accuracy and precision. In contrast, the calculation used to determine fishing mortality status F=M=0.15 is not robust to scale because it changes in proportion to the overall scale estimated by the assessment model.

In this appendix we estimate the probability of overfishing/overfished status for the entire stock and for the southern component by comparing projections against a wide range of possible biomass scales and catch levels (see TOR 4 and TOR 7 in the main document for the methods used in calculating overfished/overfishing status).

If the true catchability *q* for the NEFSC clam survey is higher than estimated in the basecase assessment, then the true biomass will be lower than estimated and *vice-versa*. The *q* estimated in the basecase model was 0.33, which was approximately equal to the 64th percentile of our prior distribution. It is possible that we misestimated *q*. With this in mind, one our sensitivity tests assumes that the true *q* is equal to the 75th percentile of our prior distribution so that true biomass levels are substantially lower than estimated in the basecase model. Other sensitivity analyses assume that the true *q* is equal to the 25th percentile of our prior distribution so that the true biomass level is much higher than estimated in the basecase model. These values of *q* produce a wide range of biomass estimates (Table A9.1). The two sensitivity runs are hereafter referred to as "high *q*" and "low *q*" and will be compared to the actual assessment runs called "basecase".

In projection scenarios we used the estimated *q* (0.33 = basecase) to calculate reference points. The population variables (biomass and F) estimated in the high *q* and low *q* model runs were compared to the basecase reference point to determine the status of the population. This scenario demonstrates the possible outcomes of a situation in which the assessment was incorrect regarding scale, and the true scale of the biomass is considerably higher or lower than we believe. We tested several catch levels in projection scenarios, described in the main body of the report. In order of increasing catch they are: status quo, quota and OFL (see TOR 7 and Table A9.2). These catch levels were prorated between the southern area where most fishing occurs and GBK as described in the main body of the report (TOR 7). Separate simulations were run for the southern area and GBK and the results each pair of simulations were combined to evaluate effects on the entire stock.

Because a high *q* results in a lower biomass, high *q* is more likely to result in an overfished/overfishing status determination. The scenario in which an overfished/overfishing designation was most likely to occur was when the population was fished at the OFL level, particularly when true biomass was lower than estimated using our basecase model (Figure A9.3). Under the high *q*-low biomass state of nature, the cumulative probability of overfished status during any of the years from 2013 – 2017 was unlikely (probability < 10%) using the status quo or quota catch levels, but was relatively likely (45%) when using the OFL catch scenario (Table A9.3). Fishing at the OFL level is not currently allowed under the surfclam FMP.

The probability of overfishing at any point during the years 2013-2017 was essentially zero (Figure A9.4) at any level of *q*, unless the catch was set at the OFL, when overfishing was almost inevitable in simulations.

In the low *q* scenario, the population was unlikely to be overfished or have overfishing occur at any point over the next five years (Table A9.3; Figure A9.5 – A9.8).

For the southern area only and high *q* state, the true biomass in 2011 tended to stay above the threshold (Figure A9.9). In the high *q* state, the annual fishing mortality trajectory fell below the F threshold, except in F=OFL scenario (Figure A9.10).

Reference points are defined for the whole stock but the maximum annual probability of a hypothetical overfished condition for the southern area using the hypothetical reference point $B_{threshold}$=B_{1999}/4 for the south in any year between 2013 and 2017 was generally less than 5% except in the F=OFL scenario, where it rose to about 17% (Figure A9.11). The cumulative probability of overfished status over that time period varies from 14% to 42% (Table A9.4; Figure A9.12). Overfished status was unlikely under all fishing scenarios when testing the low *q* state (Figures A9.13 and A9.15; Table A9.4).

The maximum annual probability of hypothetical overfishing the southern area over the years from 2013 to 2017 was zero regardless of the *q* used, unless fishing was set to the OFL (Figures A9.14 and A9.16; Table A9.4).

Overfished status determinations for the northern (GBK) area are not possible at this time due to a lack of reference points. The likely trajectory of the population biomass given the various states of *q* and fishing scenarios is available in Table (A9.2) and Figures (A9.17 – A9.18).

Overfishing the northern area is unlikely (cumulative probability through 2017 < 1%), except where fishing is set to the OFL (Figures A9.19 – A9.22; Table A9.5).

Potential effects on biomass were summarized using an additional method. We also present results based on the probability that the stock would fall below the "true" (based on the *q* being tested) value of $B_{1999}/4$ (Table A9.6). In this case the each state of nature (or q level) would have a unique reference point. In contrast, the method used in all other analyses summarizes results based on the probability that the stock falls below the $B_{1999}/4$ biomass level estimated in the basecase assessment, so that each q level is tested against the same reference point.

These sensitivities demonstrate that conclusions about the probability of overfishing or overfished stock status during 2011-2018 using the basecase model would likely not change under a wide range of true biomass levels and catches at the status-quo or quota levels. However, overfishing and overfished conditions are likely at the OFL which is currently not permitted in the FMP.

Table A9.1. Biomass in 2011 given the basecase and 2 sensitivity scenarios used as states of nature in decision table analysis, one in which the biomass was underestimated in the base case (low *q*) and one in which the biomass was overestimated (high *q*).

Region	*q*=0.11	*q*=0.33 Basecase	*q*=0.39
South	2,399,830	704,366	600,320
North	1,118,680	370,217	312,684
Total	3,518,510	1,074,583	913,004

Table A9.2. Biomass in projections given different sensitivity scenarios involving a range of true states of nature (biomass level) and possible management actions (catch levels).

	State of nature: *q* low (B high)								
	Status-quo			Quota			F=0.15		
Year	South	North	Total	South	North	Total	South	North	Total
2011	2,399,830	1,118,680	3,518,510	2,399,830	1,118,680	3,518,510	2,399,830	1,118,680	3,518,510
2012	2,379,060	1,027,710	3,406,770	2,379,060	1,027,710	3,406,770	2,379,060	1,027,710	3,406,770
2013	2,350,010	939,531	3,289,541	2,350,010	939,531	3,289,541	2,350,010	939,531	3,289,541
2014	2,294,130	840,714	3,134,844	2,288,940	840,714	3,129,654	2,247,970	822,088	3,070,058
2015	2,298,590	753,353	3,051,943	2,288,690	753,353	3,042,043	2,213,700	722,861	2,936,561
2016	2,382,780	683,152	3,065,932	2,368,600	683,152	3,051,752	2,264,670	645,876	2,910,546
2017	2,322,830	637,951	2,960,781	2,305,000	637,951	2,942,951	2,177,370	597,389	2,774,759
2018	2,400,280	668,168	3,068,448	2,379,180	668,168	3,047,348	2,230,390	626,192	2,856,582
2019	2,488,280	710,556	3,198,836	2,464,300	710,556	3,174,856	2,296,280	667,943	2,964,223
2020	2,574,860	756,680	3,331,540	2,548,360	756,680	3,305,040	2,362,280	713,381	3,075,661
2021	2,657,440	803,286	3,460,726	2,628,730	803,286	3,432,016	2,425,390	758,827	3,184,217

	State of nature: *q* high (B low)								
	Status-quo			Quota			F=0.15		
Year	South	North	Total	South	North	Total	South	North	Total
2011	600,320	312,684	913,004	600,320	312,684	913,004	600,320	312,684	913,004
2012	595,561	285,915	881,476	595,561	285,915	881,476	595,561	285,915	881,476
2013	587,428	260,080	847,508	587,428	260,080	847,508	587,428	260,080	847,508
2014	576,571	227,784	804,355	571,561	227,784	799,345	532,181	209,198	741,379
2015	584,775	199,284	784,059	575,246	199,284	774,530	503,376	168,882	672,258
2016	626,825	176,141	802,966	613,143	176,141	789,284	513,398	139,021	652,419
2017	625,105	160,555	785,660	607,876	160,555	768,431	485,513	120,271	605,784
2018	659,520	166,515	826,035	639,107	166,515	805,622	496,442	124,930	621,372
2019	697,259	176,256	873,515	674,032	176,256	850,288	512,770	134,134	646,904
2020	733,435	187,321	920,756	707,722	187,321	895,043	528,862	144,568	673,430
2021	767,295	198,728	966,023	739,385	198,728	938,113	543,581	154,801	698,382

Table A9.3. Decision table for the whole surfclam stock, showing cumulative probability of overfished/overfishing status in any of the 5 years during 2013-2017, using 3 three different catch scenarios and assuming three states of nature (high, basecase and low biomass levels)

Whole stock overfished status probability

Catch	Low *q* (high B)	Basecase	High *q* (low B)
Status quo	0.001	0.019	0.082
Quota	0.001	0.022	0.098
OFL	0.002	0.122	0.448

Whole stock overfishing probability

Catch	Low *q* (high B)	Basecase	High *q* (low B)
Status quo	0	0	0
Quota	0	0	0.001
OFL	0	0.99	1

Table A9.4. Decision table for the southern area, showing cumulative probability of overfished/overfishing status in any of the 5 years from 2013-2017, using 3 three different catch scenarios and assuming three states of nature (high, basecase and low biomass levels).

Southern area overfished status probability

Catch	Low *q* (high B)	Basecase	High *q* (low B)
Status quo	0	0.053	0.136
Quota	0	0.061	0.156
OFL	0	0.163	0.42

Southern area overfishing probability

Catch	Low *q* (high B)	Basecase	High *q* (low B)
Status quo	0	0	0
Quota	0	0	0
OFL	0	0.99	1

Table A9.5. Decision table for the northern area, showing cumulative probability of overfished/overfishing status in any of the 5 years from 2013-2017, using 3 three different catch scenarios and assuming three states of nature (high, basecase and low biomass levels).

Northern area overfishing probability

Catch	Low *q* (high B)	Basecase	High *q* (low B)
Status quo	0	0	0.002
Quota	0	0	0.003
OFL	0	0.99	1

Table A9.6. Decision table for the whole stock and southern area, showing cumulative probability of overfished/overfishing status in any of the 5 years from 2013-2017, using 3 three different catch scenarios, and assuming three states of nature (high, basecase and low biomass levels). In this case the biomass reference point is derived from each assessment outcome (i.e. in the low q outcome, the reference point $B_{1999}/4$ is based on the low q biomass in 1999).

Whole stock overfished status probability

Catch	Low q (high B)	Basecase	High q (low B)
Status quo	0.001	0.019	0.004
Quota	0.001	0.022	0.006
OFL	0.002	0.122	0.118

Southern area overfished status probability

Catch	Low q (high B)	Basecase	High q (low B)
Status quo	0.003	0.053	0.027
Quota	0.004	0.061	0.032
OFL	0.006	0.163	0.139

Figure A9.1 Biomass results for projections with the high *q* (low biomass) scenario in which true whole stock biomass was substantially lower than estimated in the basecase model. The biomass reference point is from the basecase model.

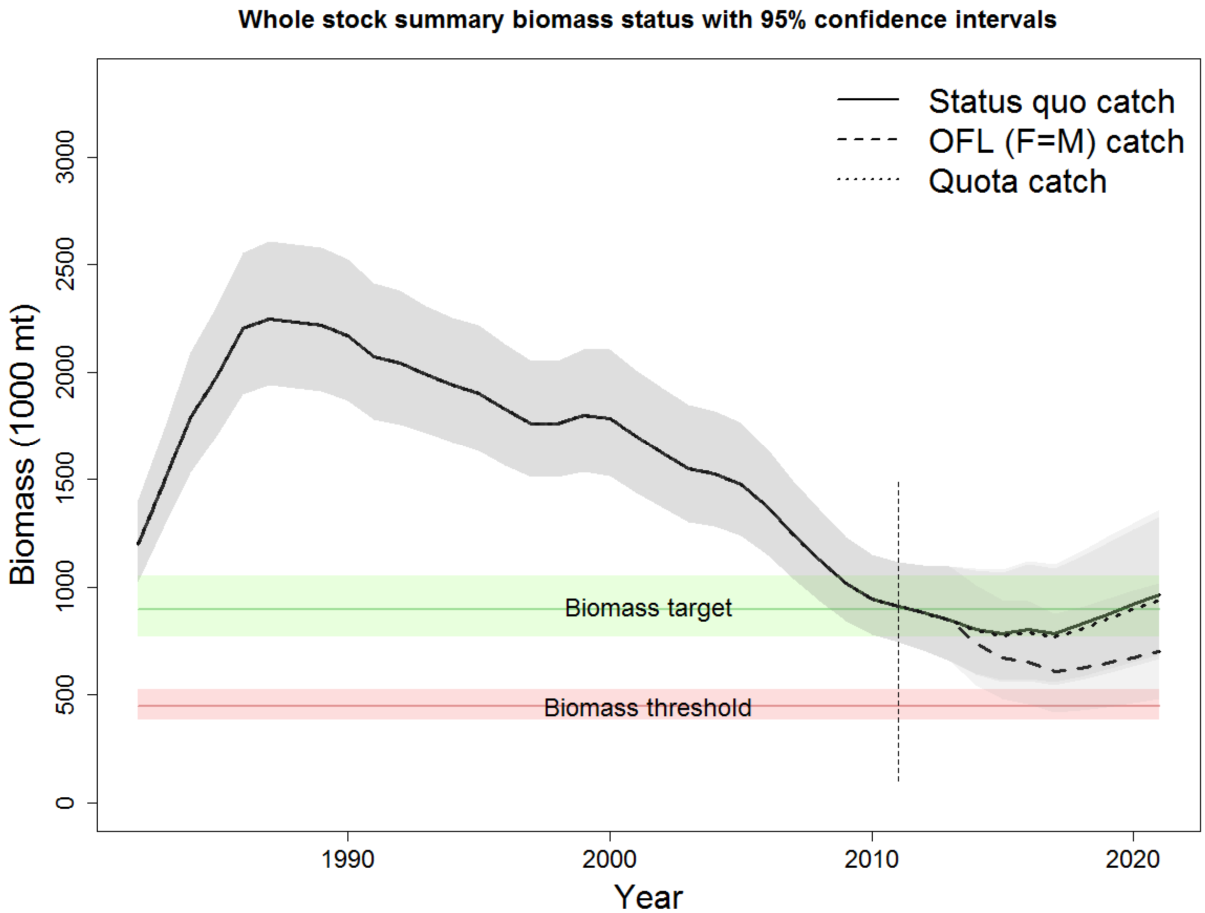


Figure A9.2. Fishing mortality results for projections with the high *q* (low biomass) scenario in which true whole stock biomass was substantially lower than estimated in the basecase model.

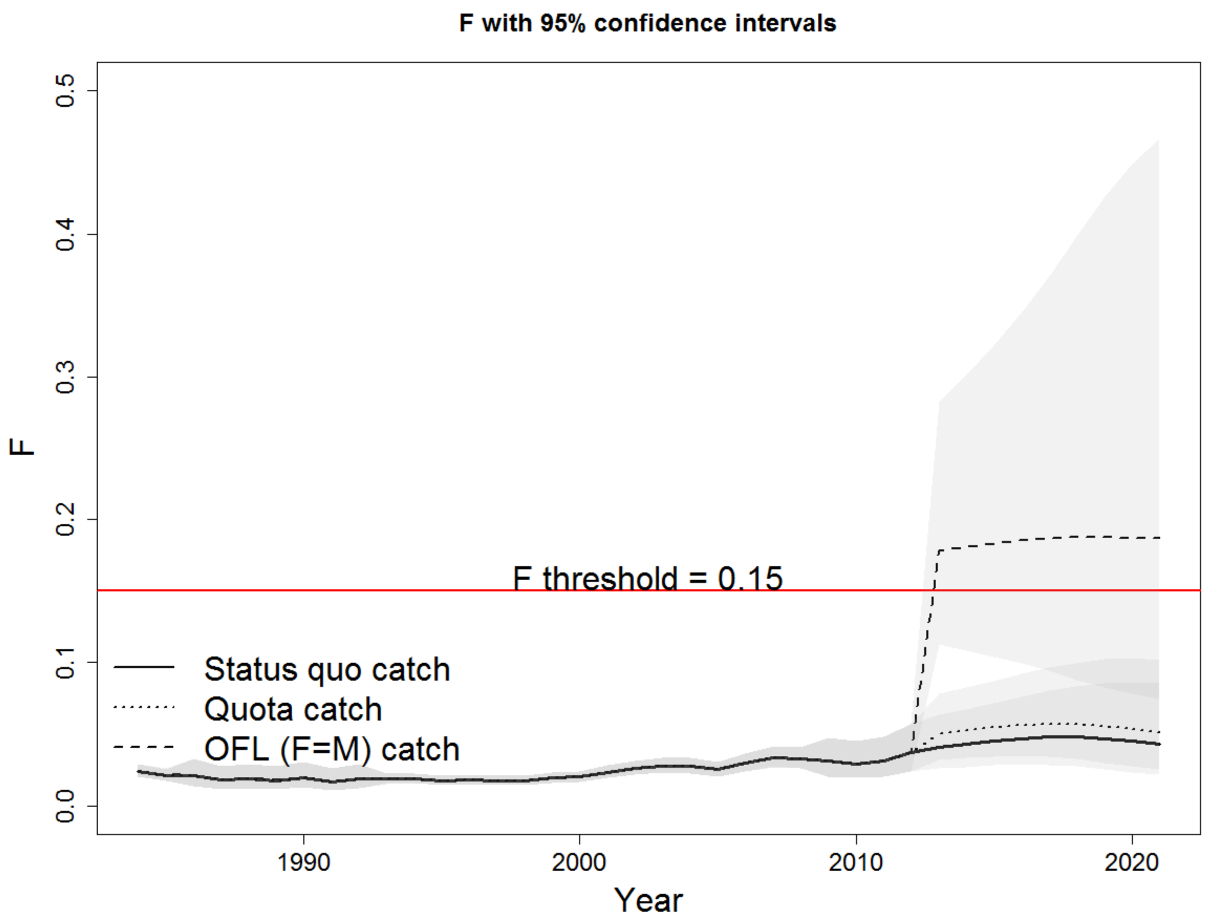


Figure A9.3. Biomass results for projections with the high *q* (low biomass) scenario in which whole stock biomass was substantially lower than estimated in the basecase model. Probabilities are for overfished stock status occurring given the minimum biomass projected between 2013-2017. The biomass reference point is from the basecase model.

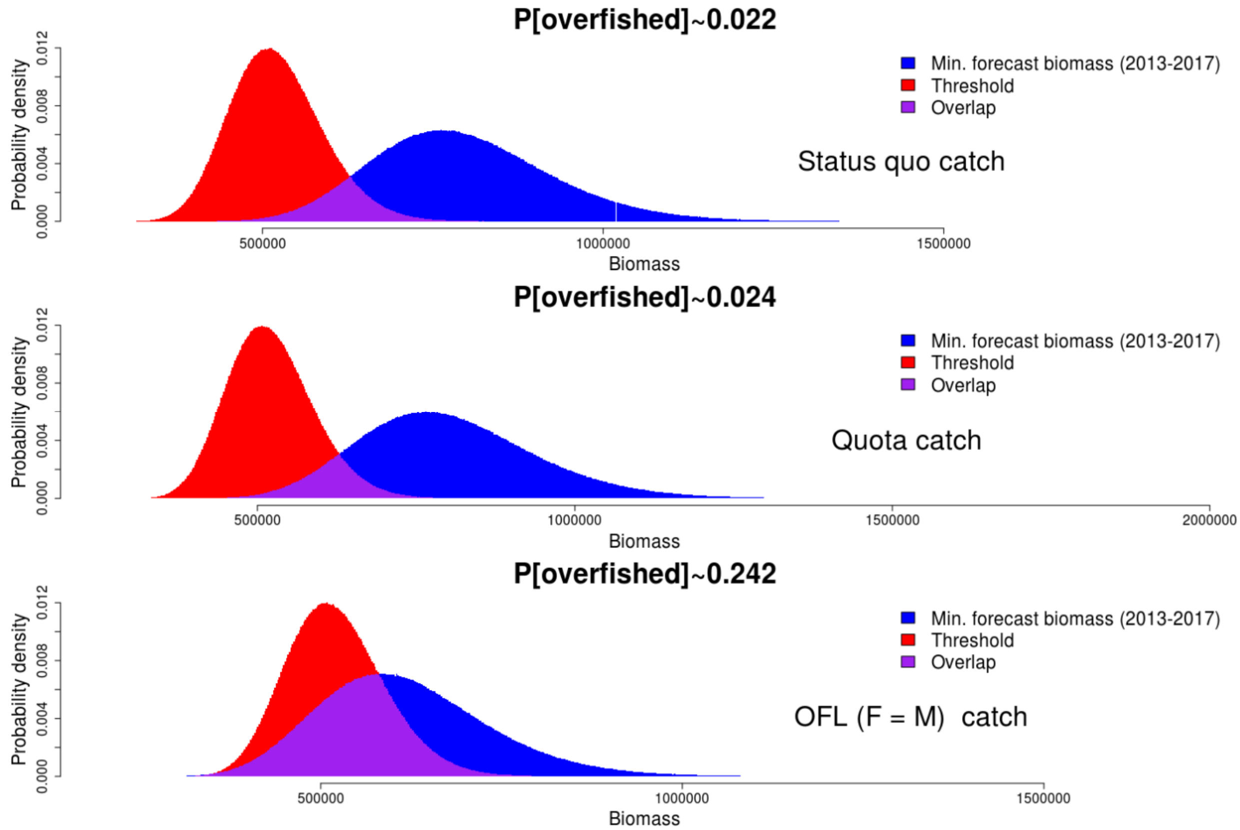


Figure A9.4. Fishing mortality results for projections with the high *q* (low biomass) scenario in which whole stock biomass was substantially lower than estimated in the basecase model. Probabilities are for overfishing occurring given the minimum biomass projected between 2013-2017.

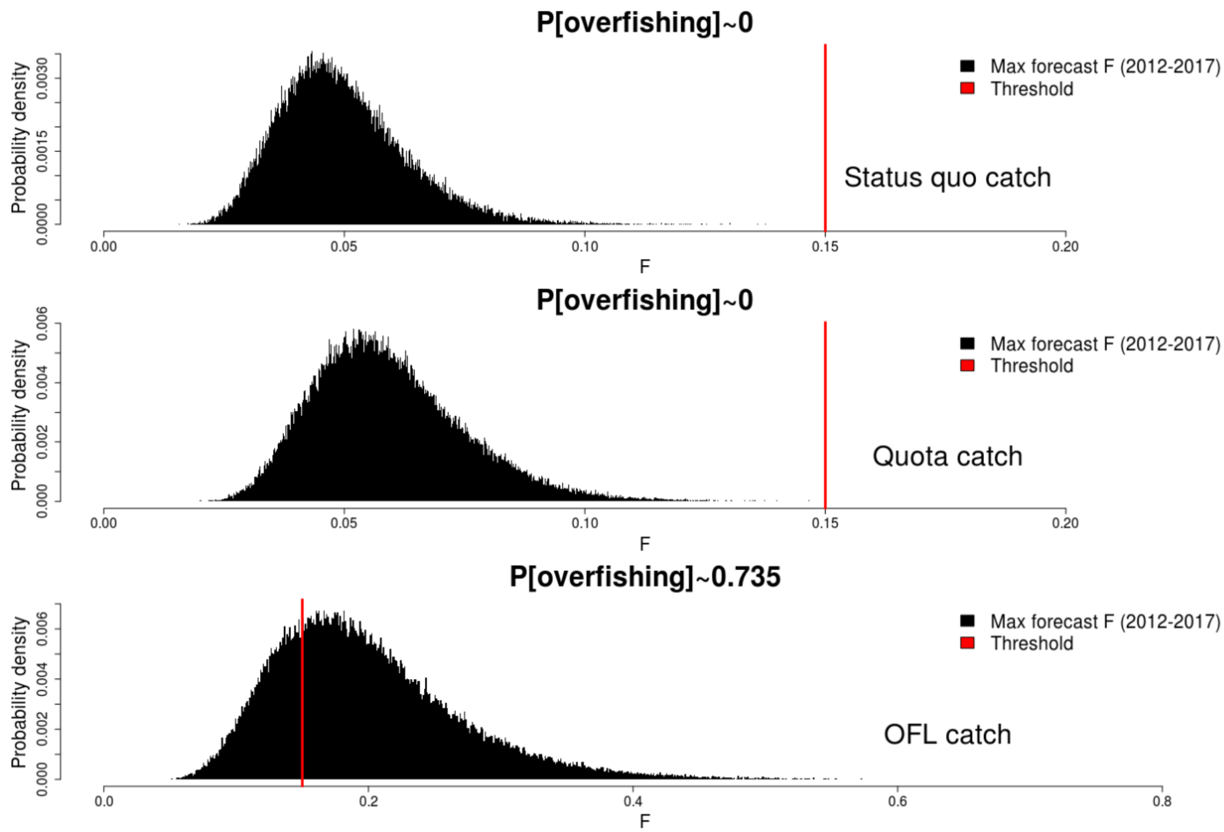


Figure A9.5. Biomass results for projections with the high *q* (low biomass) scenario in which true whole stock biomass was substantially larger than estimated in the basecase model. The biomass reference point is from the basecase model.

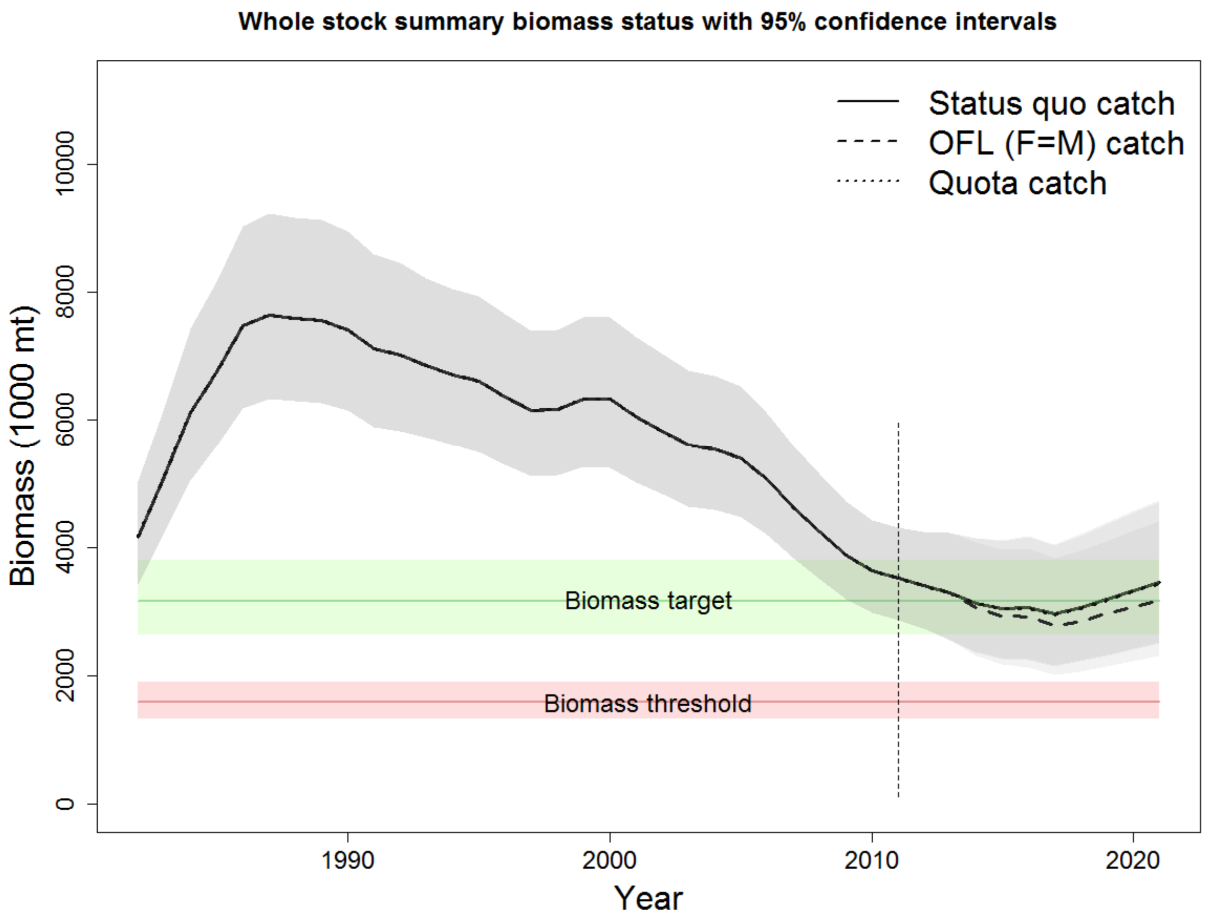


Figure A9.6. Fishing mortality results for projections with the low *q* (high biomass) scenario in which true whole stock biomass was substantially larger than estimated in the basecase model.

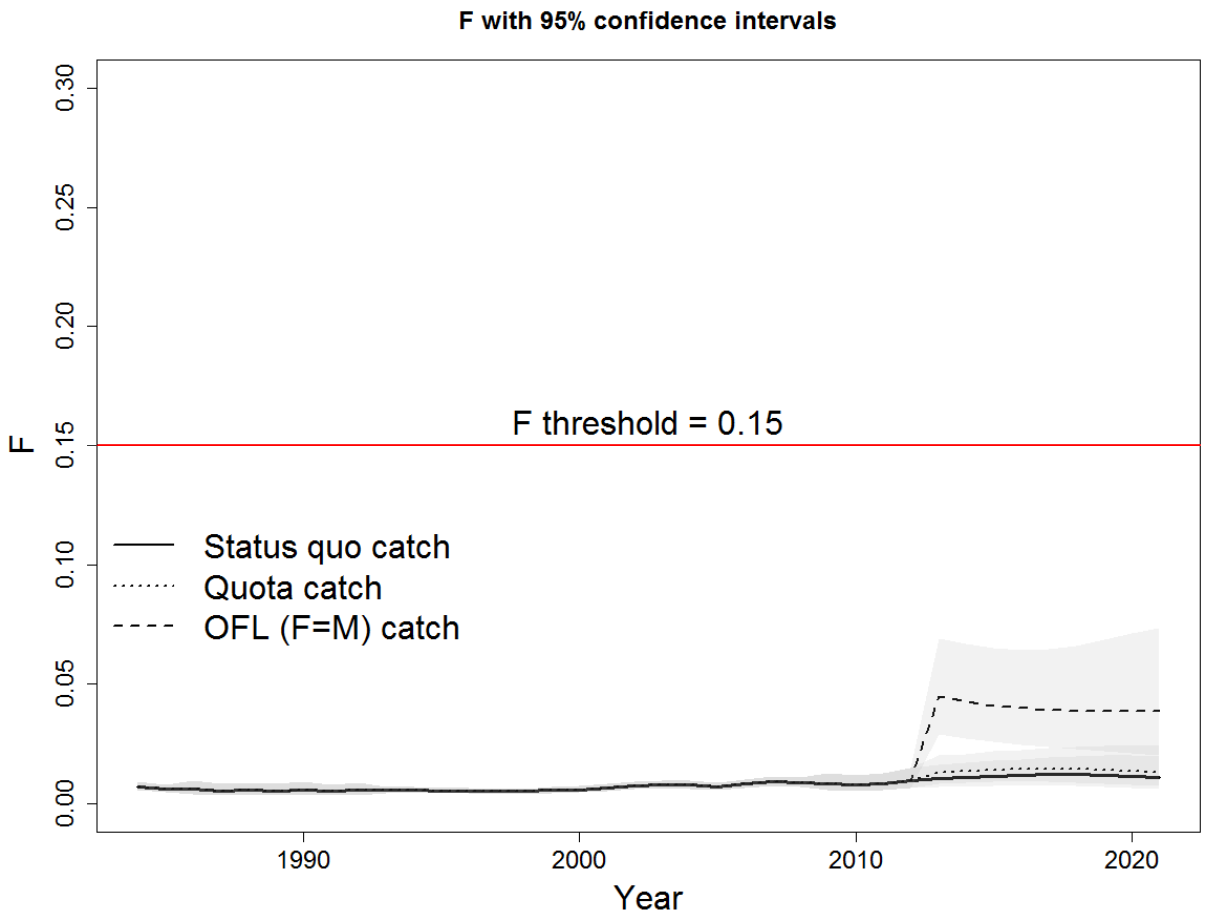


Figure A9.7. Biomass results for projections with the low *q* (high biomass) scenario in which whole stock biomass was substantially larger than estimated in the basecase model. Probabilities are for overfished stock status occurring given the minimum biomass projected between 2013-2017. The biomass reference point is from the basecase model.

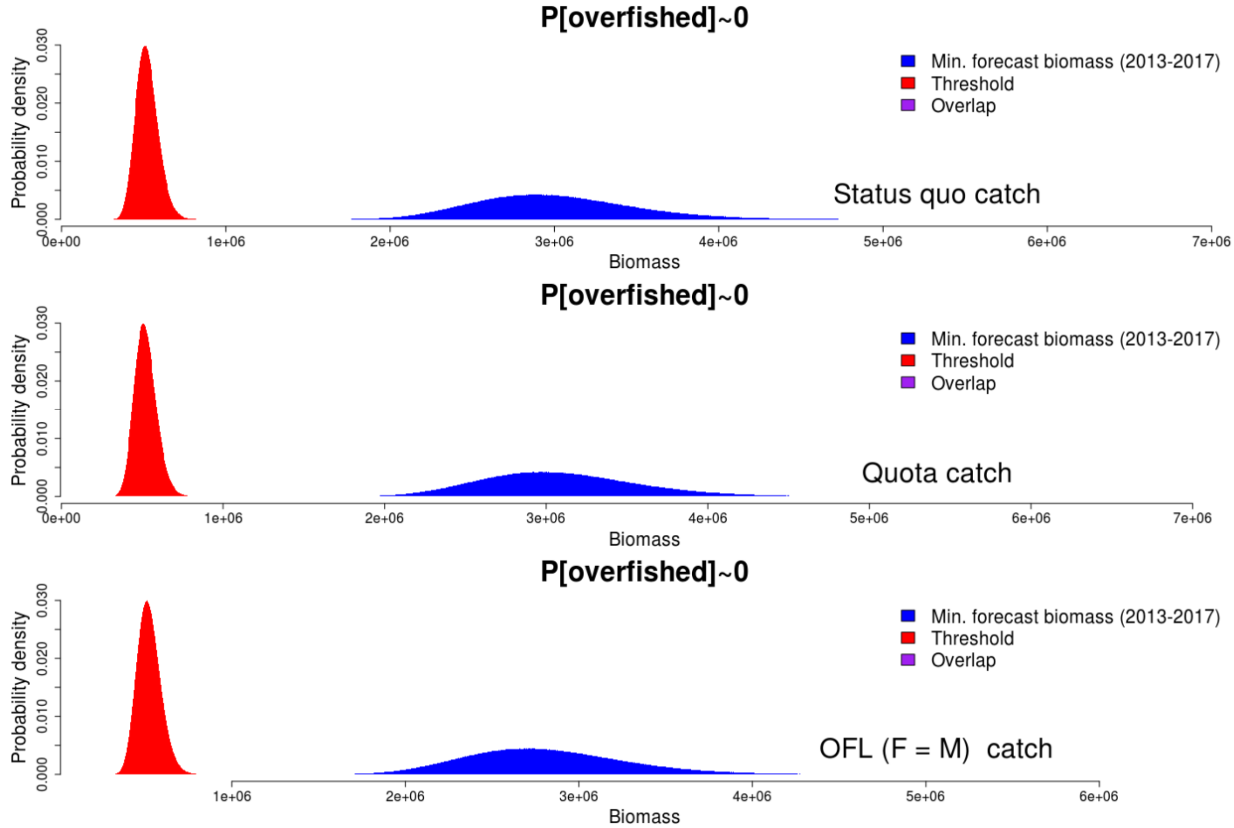


Figure A9.8. Fishing mortality results for projections with the low *q* (high biomass) scenario in which whole stock biomass was substantially larger than estimated in the basecase model. Probabilities are for overfishing occurring given the minimum biomass projected between 2013-2017.

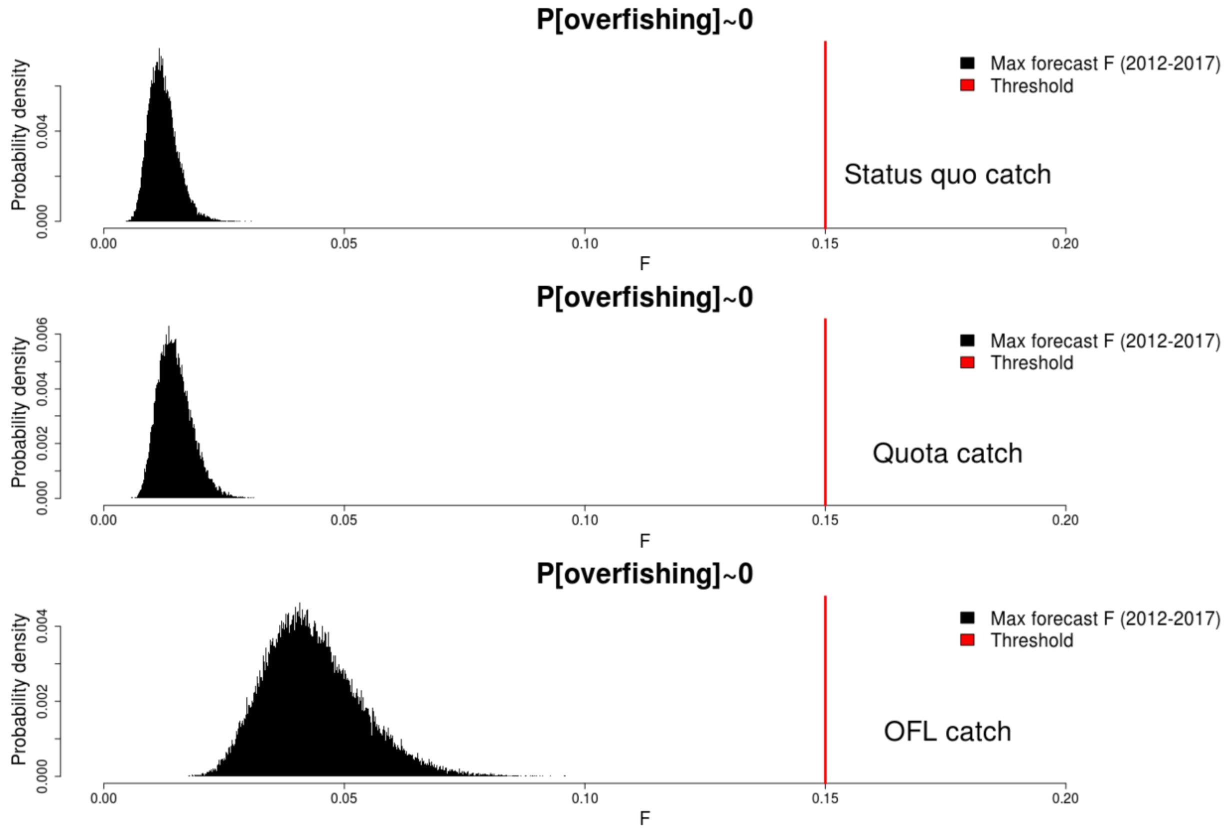


Figure A9.9. Biomass results for projections with the high *q* (low biomass) scenario in which true southern area biomass was substantially lower than estimated in the basecase model. The biomass reference point is from the basecase model.

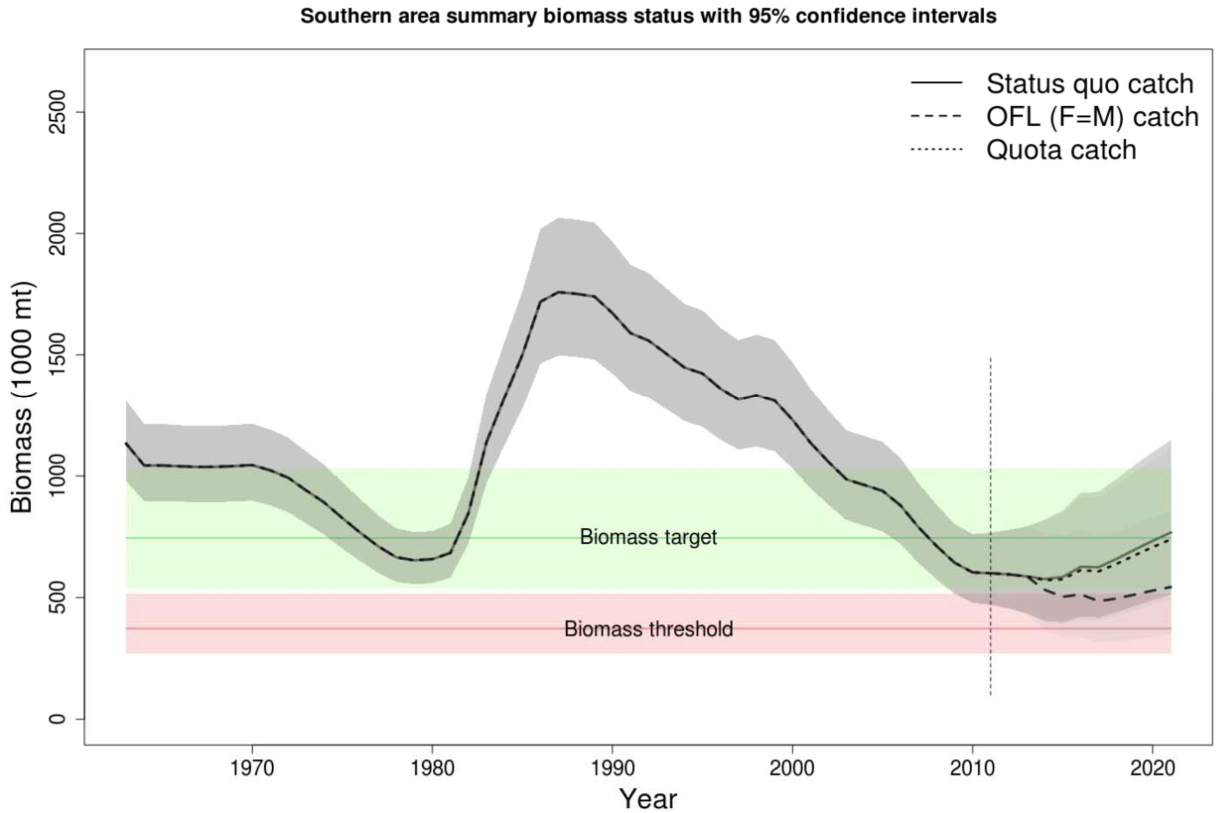


Figure A9.10. Fishing mortality results for projections with the high *q* (low biomass) scenario in which true southern area biomass was substantially lower than estimated in the basecase model.

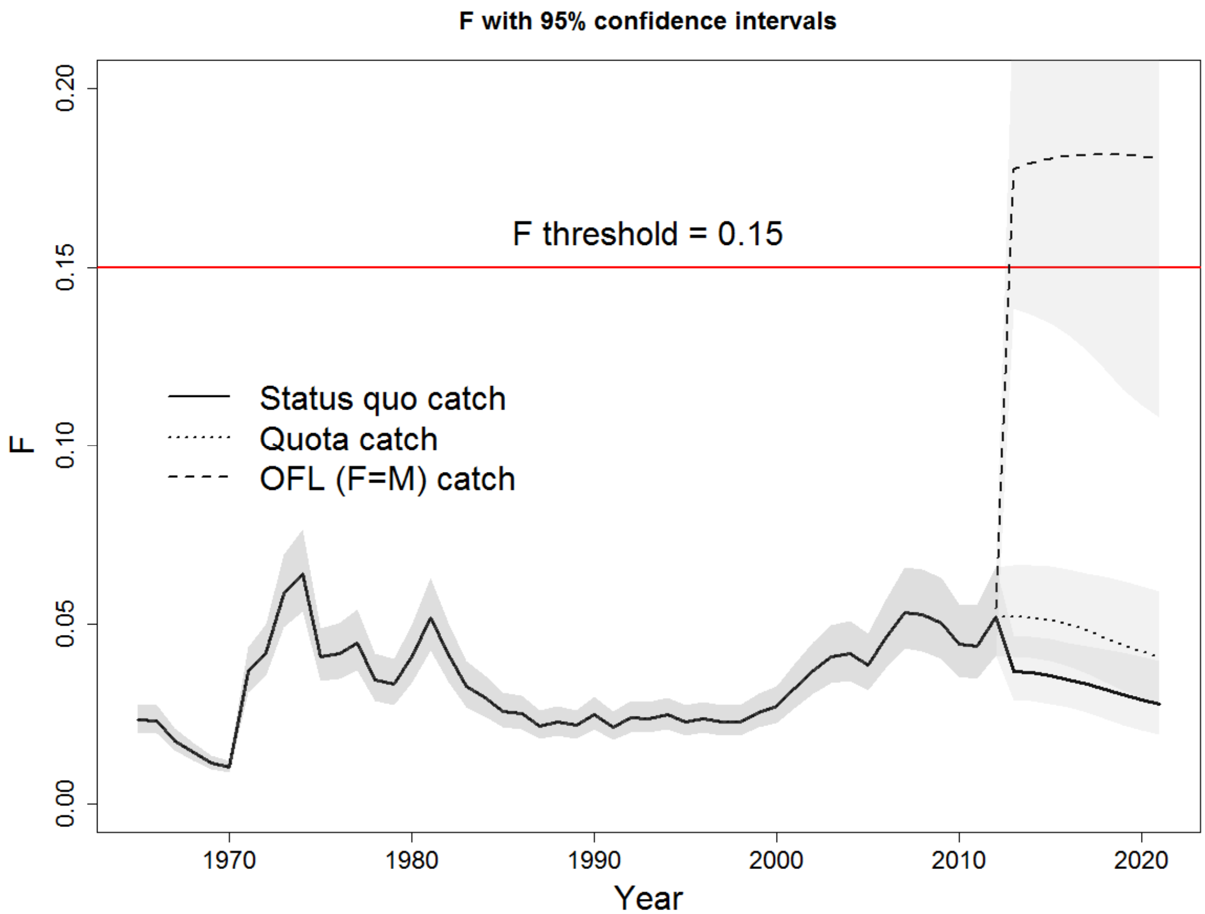


Figure A9.11. Biomass results for projections with the high q (low biomass) scenario in which southern area biomass was substantially lower than estimated in the basecase model. Probabilities are for overfished stock status occurring given the minimum biomass projected between 2013-2017. The biomass reference point is from the basecase model.

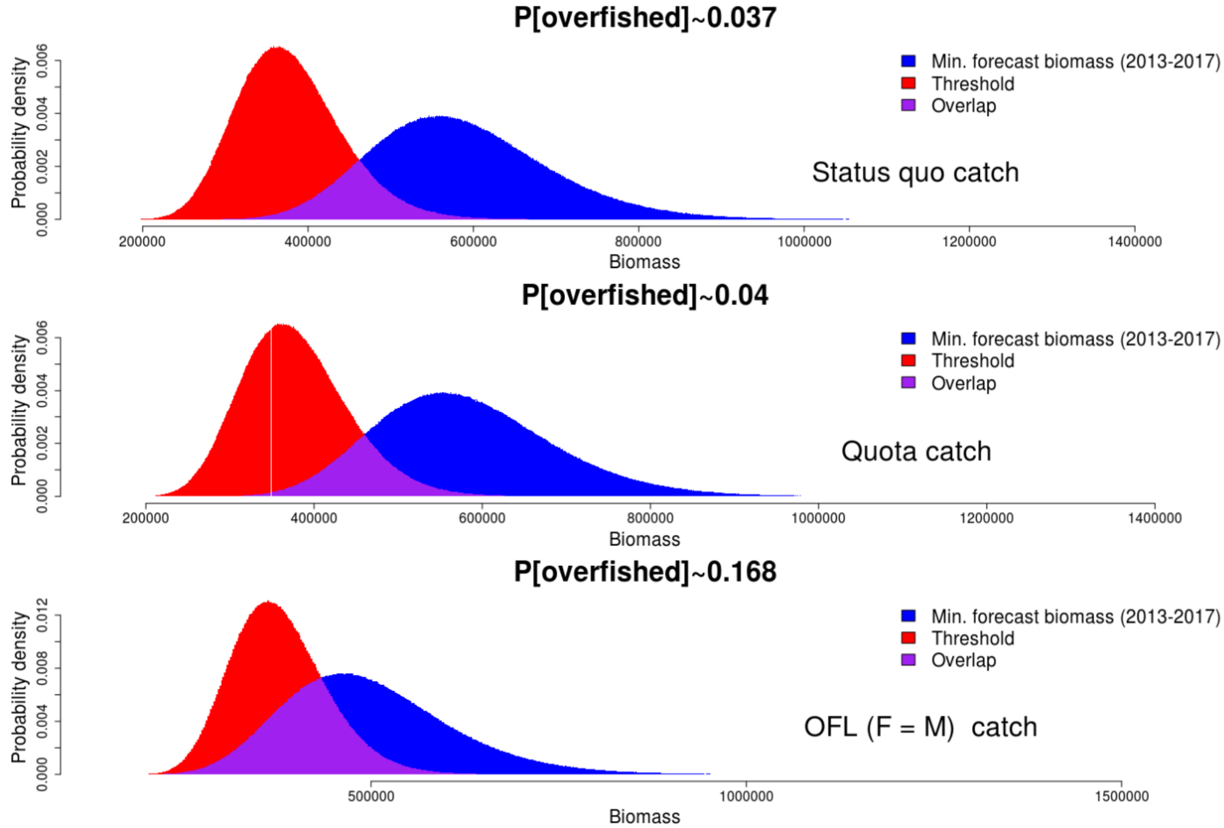


Figure A9.12. Fishing mortality results for projections with the high *q* (low biomass) scenario in which southern area biomass was substantially lower than estimated in the basecase model. Probabilities are for overfishing occurring given the minimum biomass projected between 2013-2017.

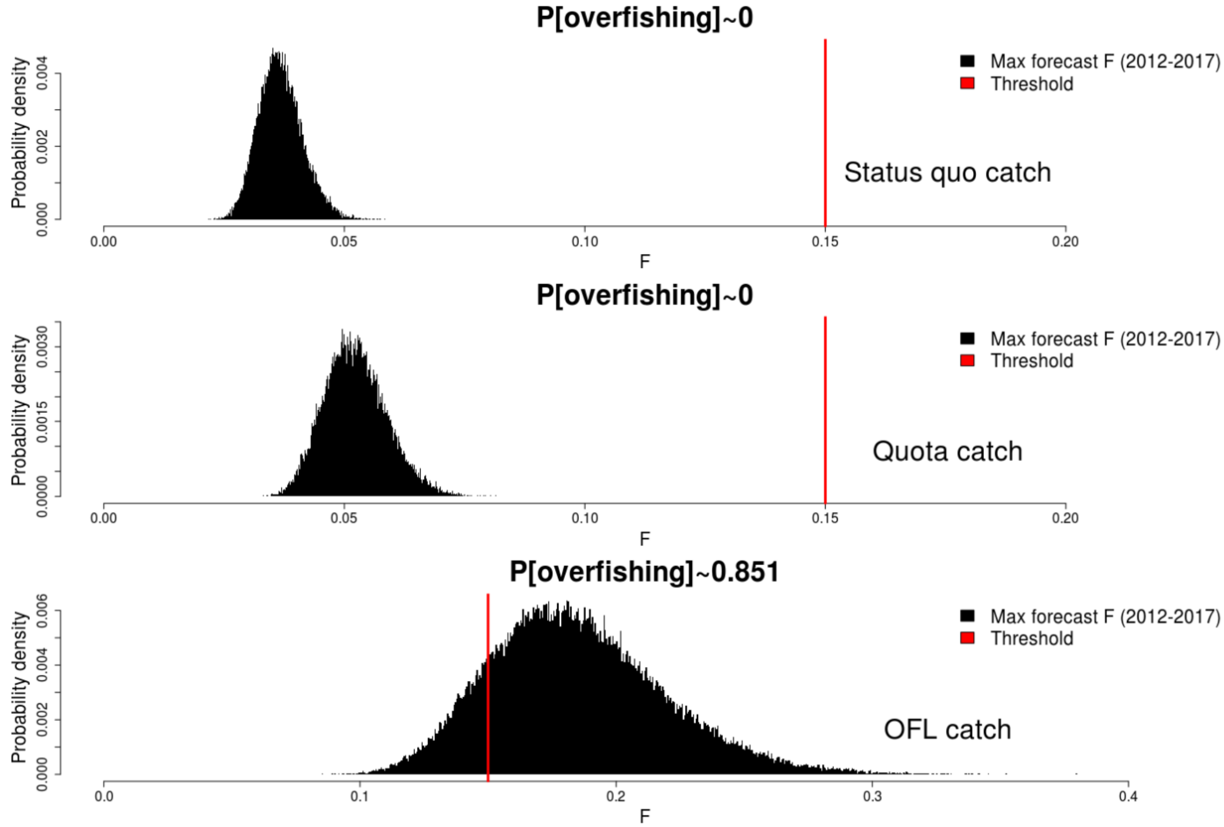


Figure A9.13. Biomass results for projections with the high *q* (low biomass) scenario in which true southern area biomass was substantially larger than estimated in the basecase model. The biomass reference point is from the basecase model.

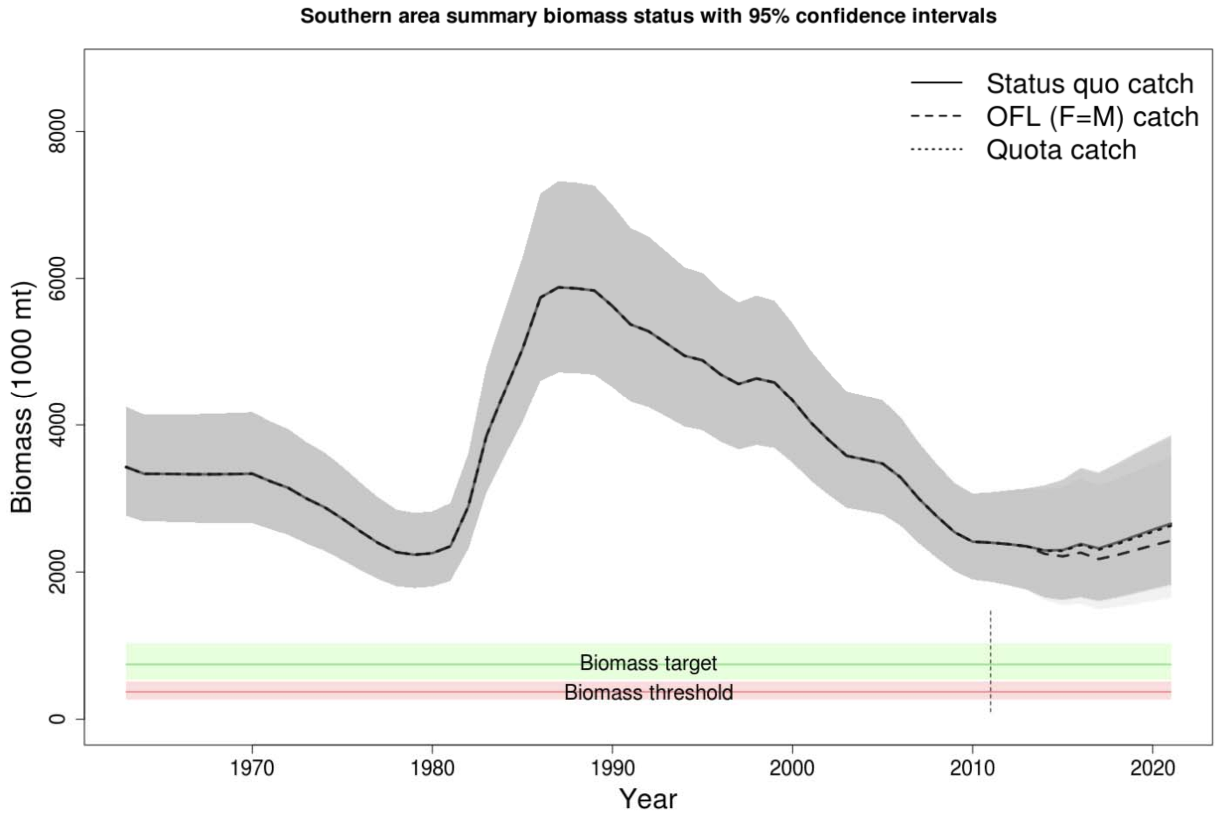


Figure A9.14. Fishing mortality results for projections with the low *q* (high biomass) scenario in which true southern area biomass was substantially larger than estimated in the basecase model.

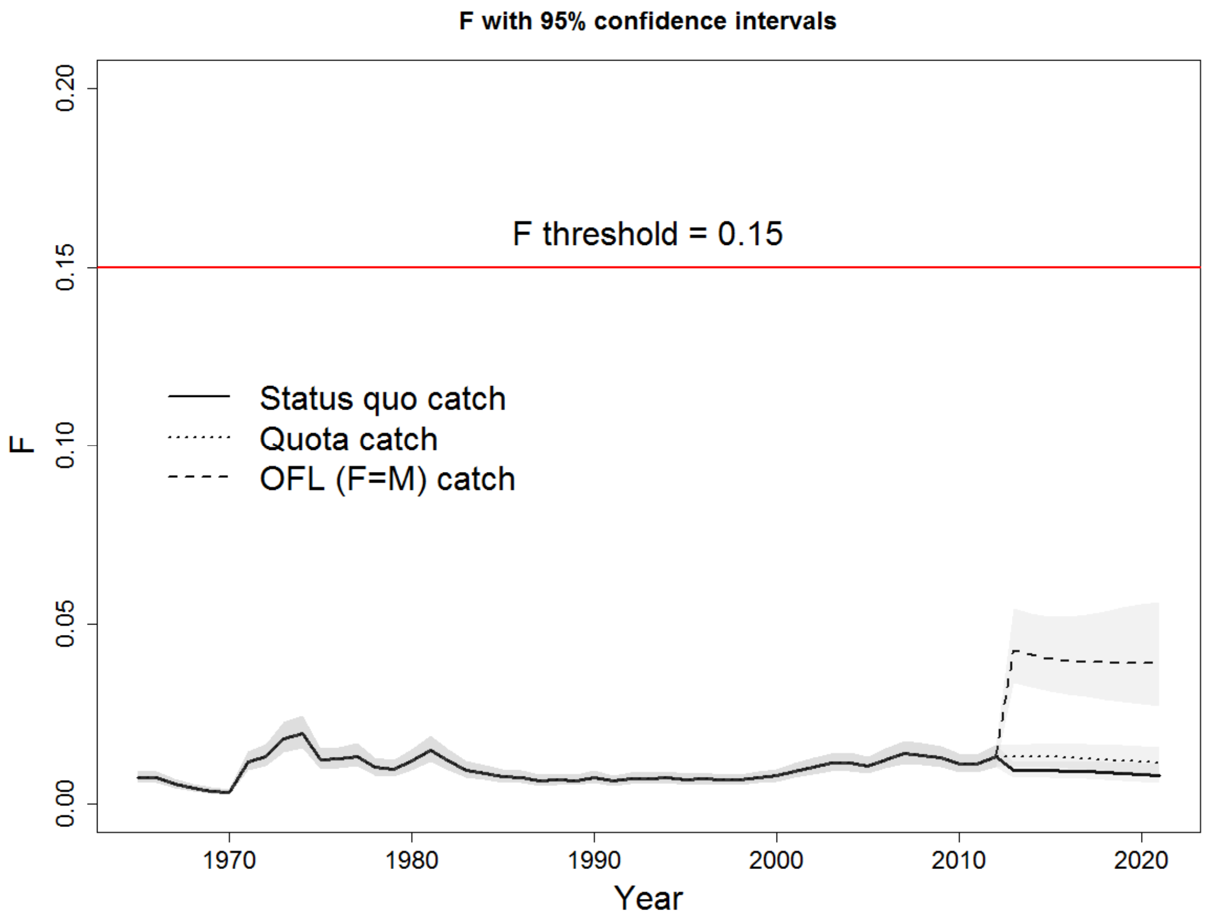


Figure A9.15. Biomass results for projections with the low *q* (high biomass) scenario in which southern area biomass was substantially larger than estimated in the basecase model. Probabilities are for overfished stock status occurring given the minimum biomass projected between 2013-2017. The biomass reference point is from the basecase model.

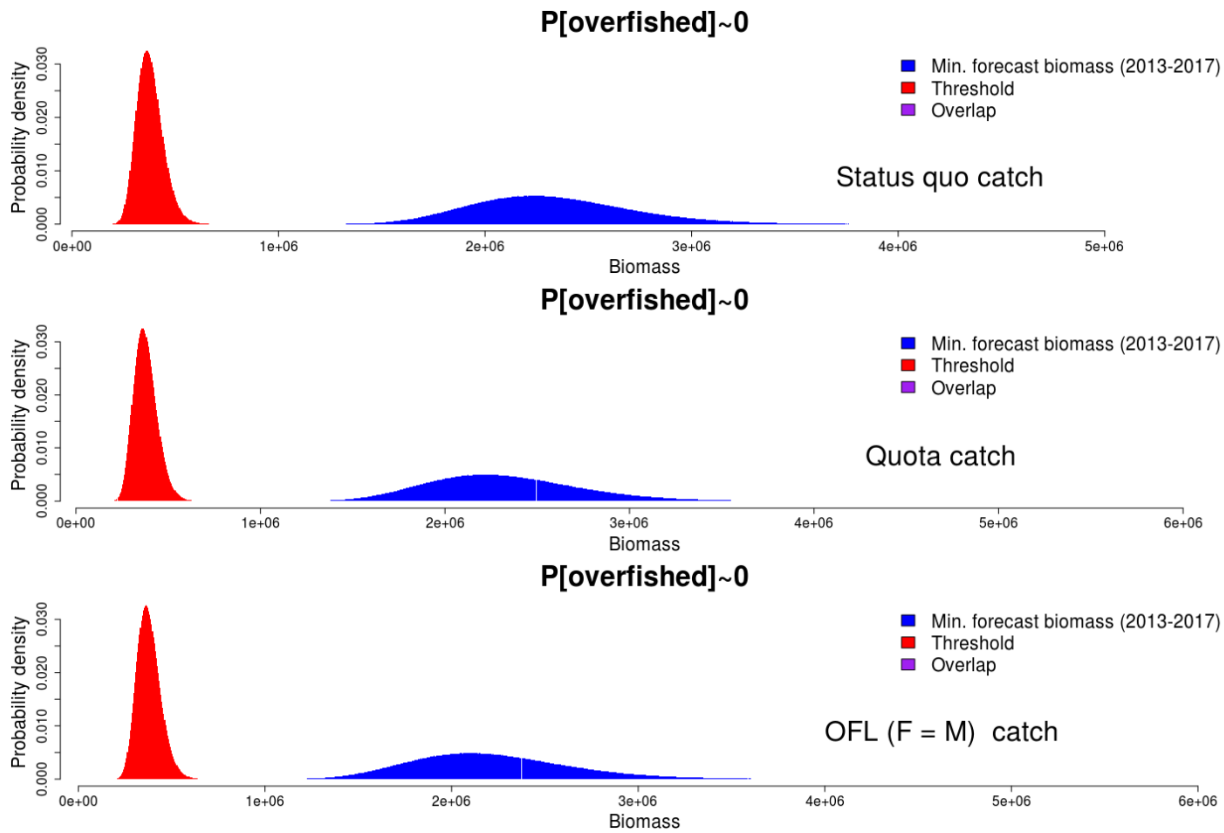


Figure A9.16. Fishing mortality results for projections with the low *q* (high biomass) scenario in which southern area biomass was substantially larger than estimated in the basecase model. Probabilities are for overfishing occurring given the minimum biomass projected between 2013-2017.

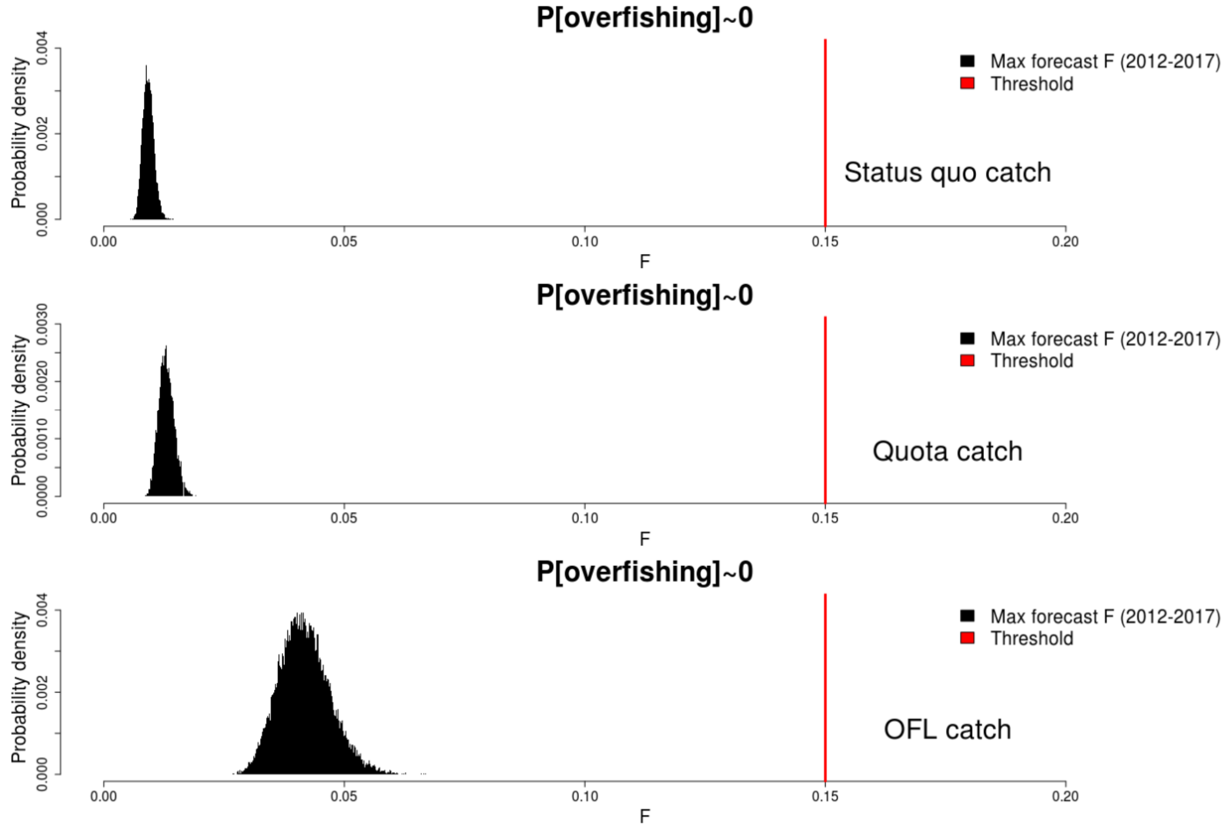


Figure A9.17. Biomass results for projections with the high q (low biomass) scenario in which true northern area biomass was substantially lower than estimated in the basecase model.

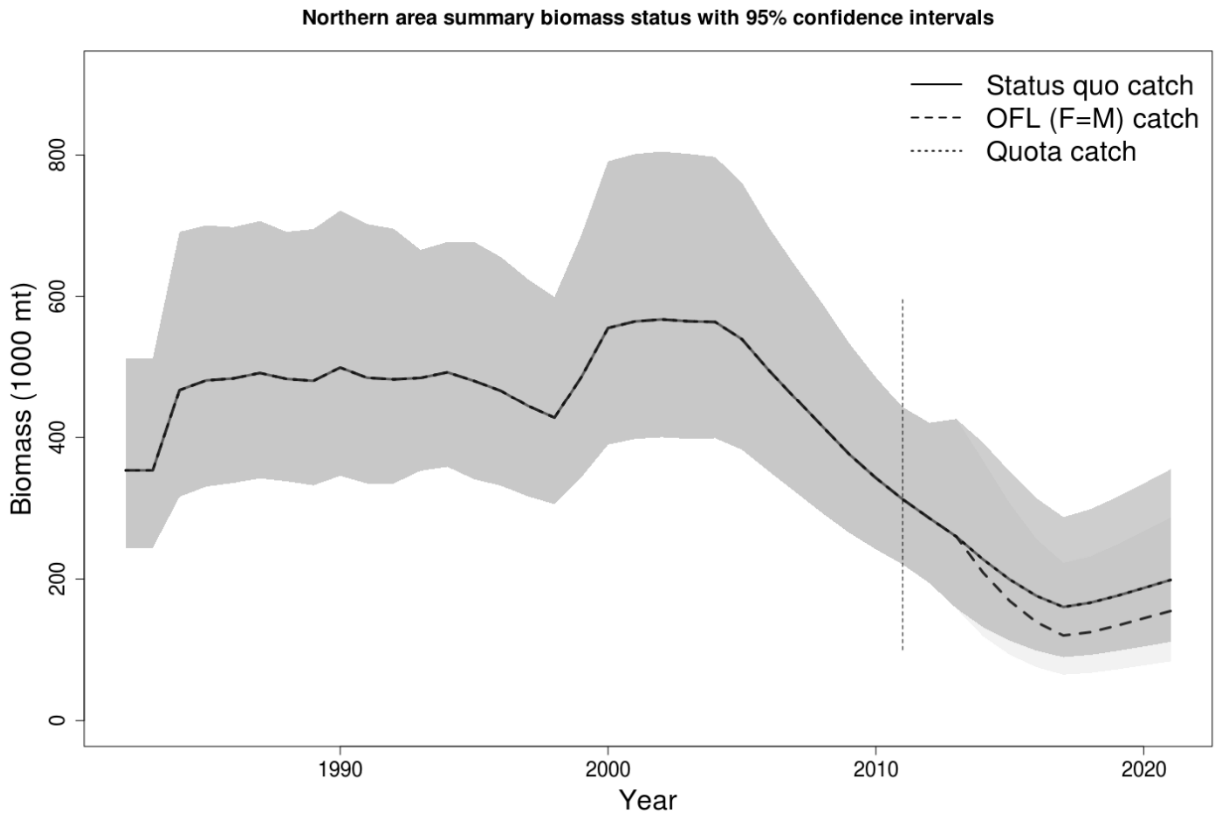


Figure A9.18 Biomass results for projections with the low *q* (high biomass) scenario in which true whole stock biomass was substantially lower than estimated in the basecase model.

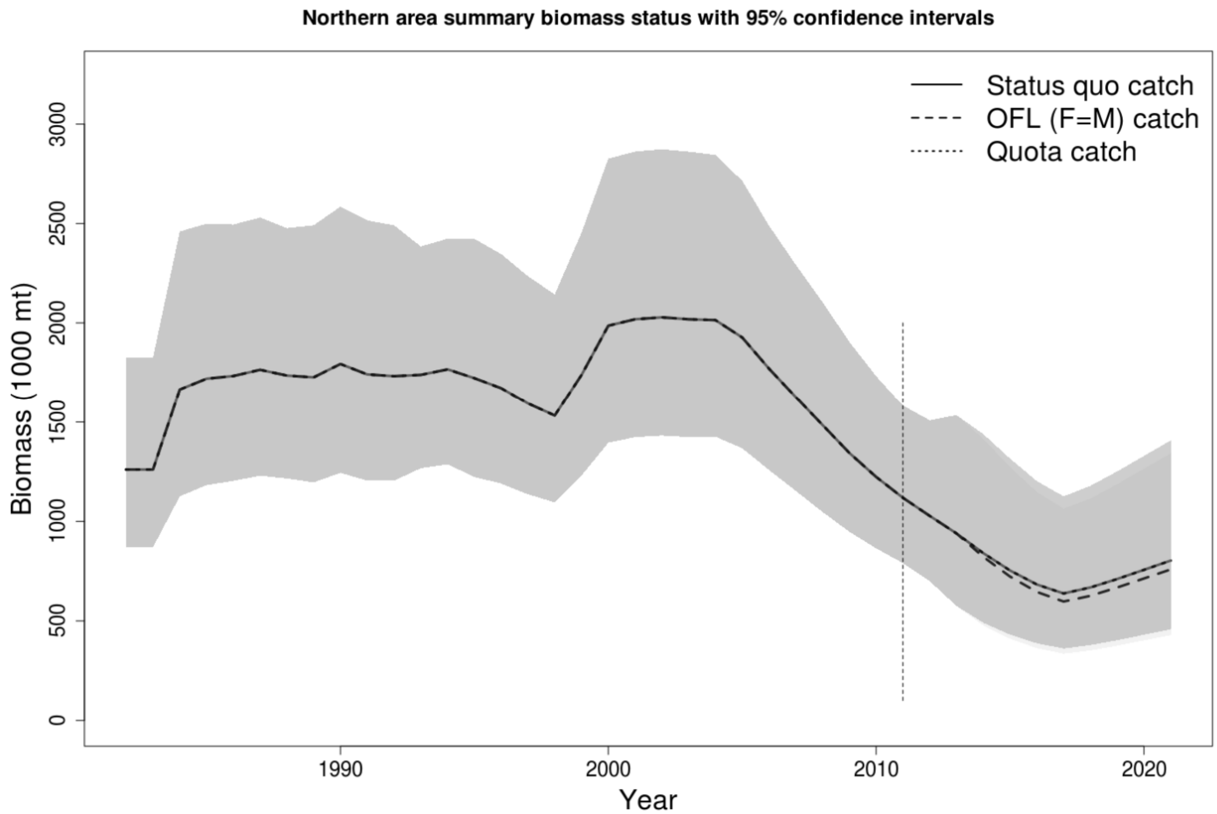


Figure A9.19. Fishing mortality results for projections with the high *q* (low biomass) scenario in which true northern area biomass was substantially lower than estimated in the basecase model.

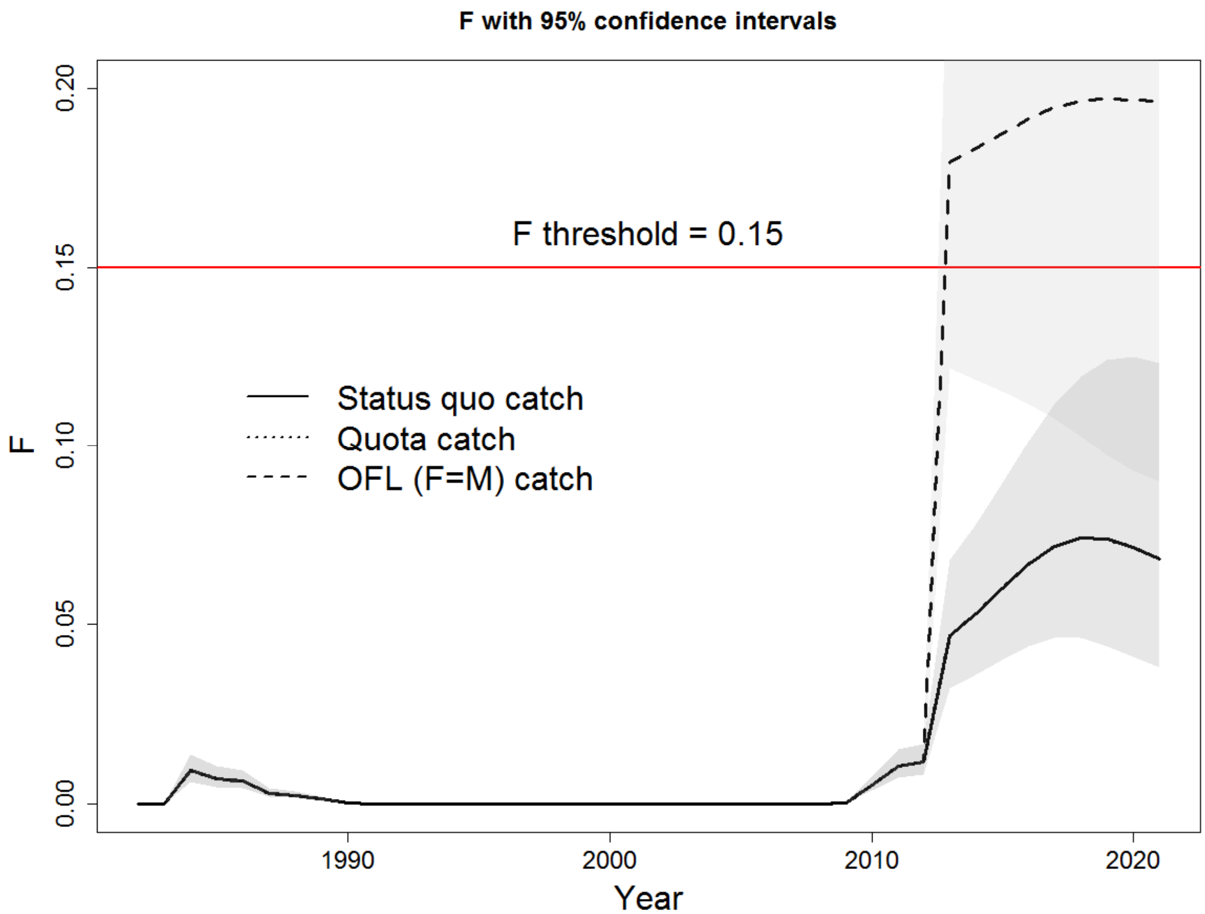


Figure A9.20. Fishing mortality results for projections with the high *q* (low biomass) scenario in which northern area biomass was substantially lower than estimated in the basecase model. Probabilities are for overfishing occurring given the minimum biomass projected between 2013-2017.

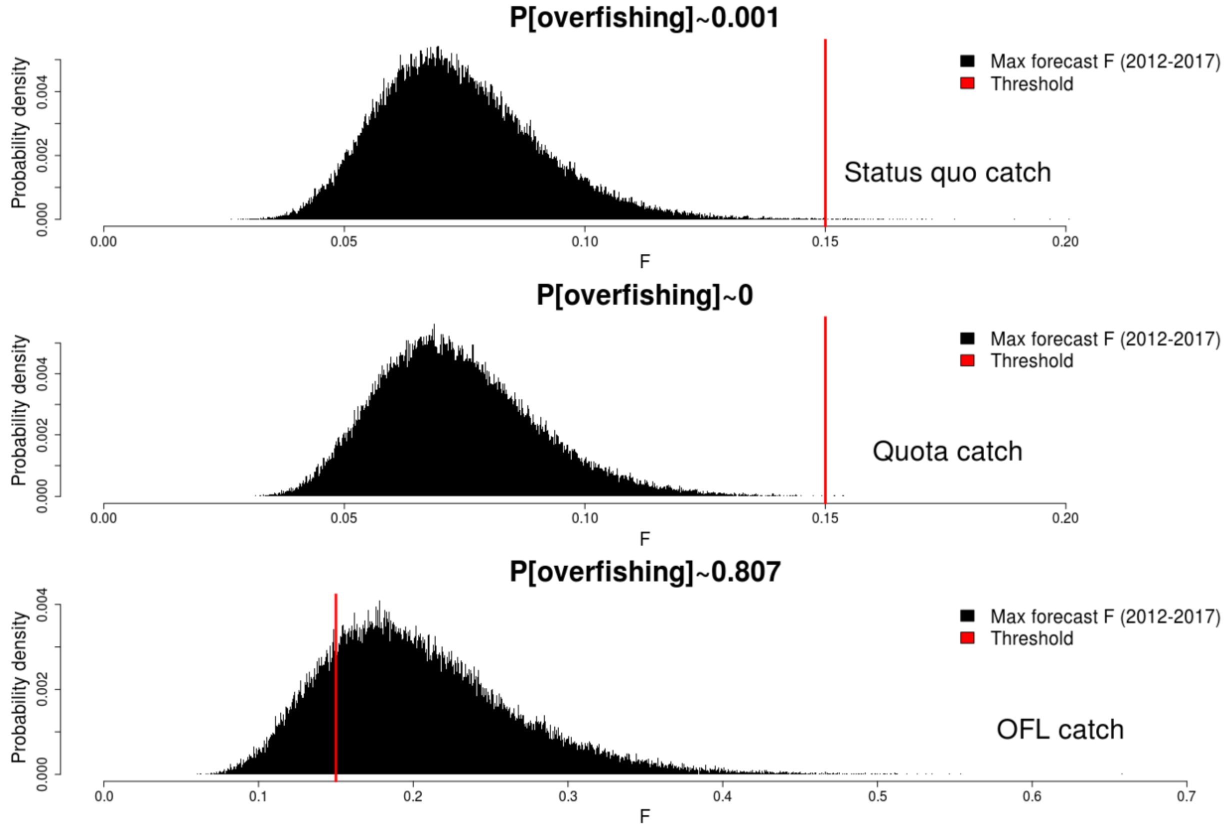


Figure A9.21. Fishing mortality results for projections with the low *q* (high biomass) scenario in which true northern area biomass was substantially larger than estimated in the basecase model.

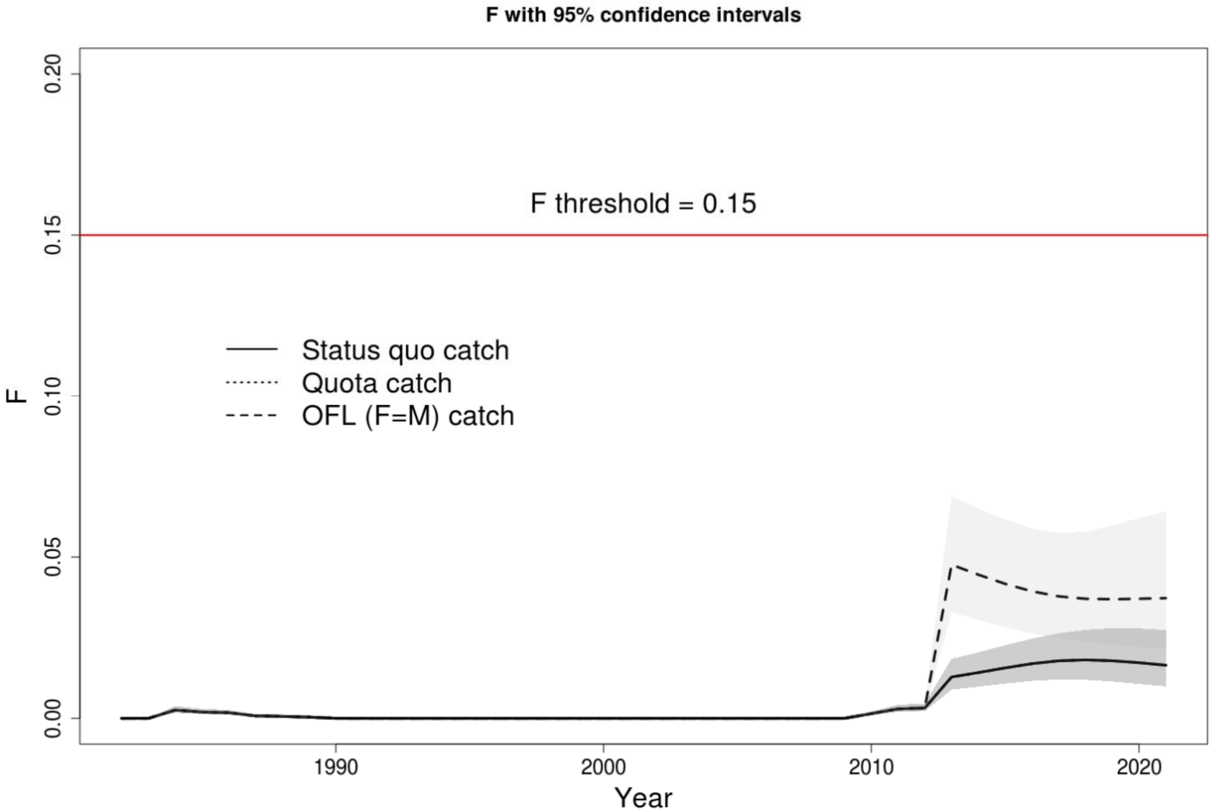
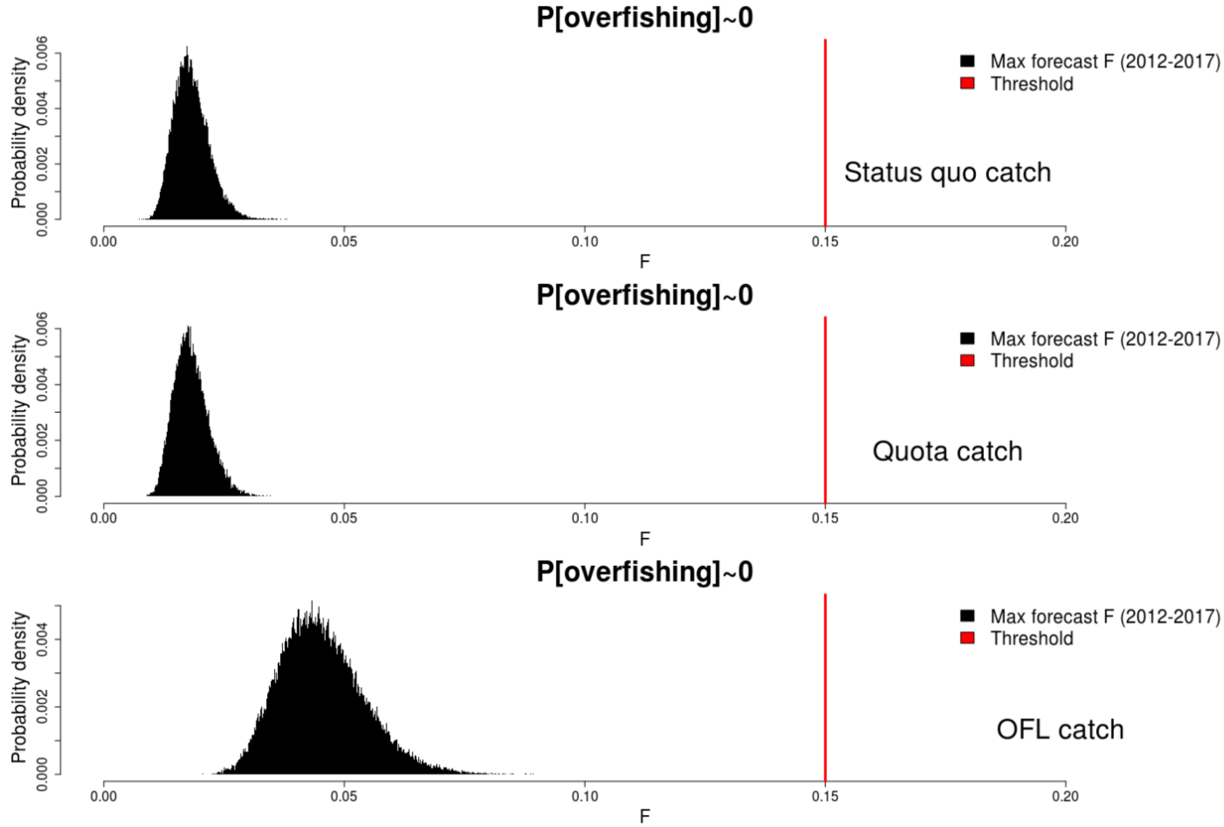


Figure A9.22. Fishing mortality results for projections with the low *q* (high biomass) scenario in which northern area biomass was substantially larger than estimated in the basecase model. Probabilities are for overfishing occurring given the minimum biomass projected between 2013-2017.



Appendix A10: Invertebrate Subcommittee

Persons who attended Invertebrate Subcommittee meetings and contributed to this report are:

Larry Jacobson (NEFSC, Chair)
Dan Hennen (NEFSC, assessment lead)
Toni Chute (NEFSC)
Chris Legault (NEFSC)
David Wallace (Wallace & Associates, Inc.)
Eric Powell (University of Southern Mississippi)
Daphne Munroe (Rutgers University)
Xinzhong Zhang (Rutgers University)
Fred Serchuk (NEFSC)
Jiashen Tang (NEFSC)
Jon Deroba (NEFSC)
Paul Rago (NEFSC)
Roger Mann (VIMS)
Tom Alspach (Sea Watch International, Inc.)
Tom Hoff (Wallace & Associates, Inc.)
Wendy Gabriel (NEFSC)
Jessica Coakly (MAFMC)
Jose Montanez (MAFMC)
Ed Houde (University of Maryland)
Doug Potts (NERO)
Guy Simmons (Sea Watch International, Inc.)
Bonnie McCray (Rutgers University)
Dvora Hart (NEFSC)
Carolyn Creed (Rutgers University)
Richard McBride (NEFSC)
Jeff Normant (NJ Division of Fish and Wildlife)
Jennifer O'Odwyer (NYSDEC)

B. GULF OF MAINE/GEORGES BANK WHITE HAKE (*UROPHYCIS TENUIS*) STOCK ASSESSMENT FOR 2013, UPDATED THROUGH 2011

The White Hake Working Group (WHWG) prepared the assessment. The working group held two meetings. The meeting dates, locations, and participants are listed below.

WHWG Data Meeting
- December 10-12, 2012
- Northeast Fisheries Science Center (NEFSC), Woods Hole, MA

WHWG Models and Biological Reference Points Meeting
- January 7-11, 2013
- Northeast Fisheries Science Center (NEFSC), Woods Hole, MA

White Hake Working Group:
Gary Shepherd – NEFSC (Chair)
Katherine Sosebee – NEFSC (Lead Scientist)
Liz Brooks – NEFSC
Doug Butterworth – University of Cape Town, South Africa
Chris Legault – NEFSC
Loretta O'Brien – NEFSC
Mike Palmer – NEFSC
Rebecca Rademeyer – University of Cape Town, South Africa
Mark Terceiro – NEFSC

White Hake Data and Model Meeting Participants:
Larry Alade – NEFSC
Jessica Blaylock – NEFSC
Jon Deroba – NEFSC
Bill Duffy – NEFSC
Ed Houde – Chesapeake Biological Lab, Univ. MD
Anna Murex – NEFSC
Julie Nieland - NEFSC
Paul Nitschke – NEFSC
Jim Odlin – Maine commercial fishermen
Paul Rago – NEFSC
Maggie Raymond - Associated Fisheries of Maine
Eric Robillard – NEFSC
Fred Serchuk – NEFSC
Sally Sherman- ME DNR
Michele Traver – NEFSC
Jim Weinberg – NEFSC
Susan Wigley – NEFSC
Tony Wood – NEFSC

TERMS OF REFERENCE (TORs)

1. Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of fishing effort. Characterize the uncertainty in these sources of data. Analyze and correct for any species misidentification in these data. Comment on the consistency of the approach to identify the catch of white hake with respect to that used in the red hake assessment.

2. Present the survey data being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, etc.). Investigate the utility of commercial or recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

3. Evaluate the utility of pooled age-length keys for development of a stock assessment model.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results. Review the performance of historical projections with respect to stock size, recruitment, catch and fishing mortality.

5. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for BMSY, BTHRESHOLD, FMSY and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

6. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model developed for this peer review. In both cases, evaluate whether the stock is rebuilt.

a. If possible update the ASPM with new data and evaluate stock status (overfished and overfishing) with respect to the relevant BRP estimates.

b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

7. Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., the probability density function) of the OFL (overfishing level) and candidate ABCs.

a. Provide numerical annual projections (3-5 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).

b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.

c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

8. Evaluate the validity of the current stock definition, taking into account what is known about migration among stock areas. Make a recommendation about whether there is a need to modify the current stock definition for future stock assessments.

9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in the most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

EXECUTIVE SUMMARY

TOR 1. Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of fishing effort. Characterize the uncertainty in these sources of data. Analyze and correct for any species misidentification in these data. Comment on the consistency of the approach to identify the catch of white hake with respect to that used in the red hake assessment.

Landings of white hake were summarized from 1893-2011.The landings in the early part of the time series are almost double any landings since 1964. Landings from the stock unit in the late 1960s were low at about 1,200 mt, and then increased through the 1970s and 1980s, peaking in 1992 at 9,600 mt. Landings then decreased to about 1,400 mt by 2008, and were about 3,000 mt in 2011. The major gear type is otter trawl followed by sink gill net. The second half of the year generally accounts for higher landings than the first half. A new source of landings (red/white hake market category) was split between red and white hake to better account for removals. For the first time, recreational catch was summarized but have not been included in the stock assessment model since there are no length data available to characterize the length/age composition. Discards were estimated using the SBRM protocol. The approach used to estimate white hake catch using nominal landings and discards is now consistent with the red hake assessment. Spatial distribution of landings, effort, and observer coverage was presented. There appears to be a concentration of landings in the otter trawl fishery in recent years. Length and age composition of landings, discards and total catch were developed.

TOR 2. Present the survey data being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, etc.). Investigate the utility of commercial or recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

Landings per unit effort (LPUE) were analyzed for the otter trawl and gill net fisheries. For the otter trawl fishery, all trips as well as those trips for which white hake accounted for more than forty percent of the landings (directed trips). The LPUE index for all trips showed that LPUE in 2011 was at the time series high. The directed LPUE and the gill net LPUE had increased but were not the highest values in the time series.

Indices of abundance and biomass were presented for the NEFSC spring and autumn surveys, ASMFC shrimp survey, Massachusetts DMF spring and fall surveys, and ME/NH spring and fall surveys. NEFSC spring stratified mean number and weight/tow indices declined from 1990 to 1997 and have slowly increased. The autumn weight per tow index fluctuated around 5 kg/tow in the early 1960s and increased to approximately 12 kg/tow during the 1970s. The autumn weight per tow index fluctuated around 10 kg/tow from 1983 to 1993. The index then declined to below 4 kg/tow in 1999, increased due to a moderately good year class. Following a decline through 2007, the index has since increased. The biomass index from the ASMFC shrimp survey shows a decline through 1997, an increase through 2002 and no trend since 2002. The Massachusetts DMF and ME/NH surveys were very variable. Length compositions were shown for all of the surveys. Age compositions for the NEFSC spring and fsll surveys were developed using survey age-length data while the MA DMF and ME/NH surveys were aged using length-slicing.

TOR 3. Evaluate the utility of pooled age-length keys for development of a stock assessment model.

An evaluation of the utility of pooled ALKs in developing a stock assessment model was conducted. Two stock assessment models were run using four sets of age compositions derived using pooled and non-pooled ALKS. The results of each model were similar under the four options. The differences were more striking between models than between age compositions. Reference points were derived for each of the possibilities and the terminal year stock sizes compared to the reference points. Stock status was the same across models and age composition type.

TOR 4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results. Review the performance of historical projections with respect to stock size, recruitment, catchand fishing mortality.

The ASPM assessment model used for the most recent assessment of white hake (GARM III, 2008) was updated to account for the major changes to the data inputs as well as four additional years of catch and survey data. The major changes to the input data include:

-*Updated length-weight equations.*

-*Updated maturity ogive.*

-*Re-estimated commercial landings-at-age.*

-*Re-estimated discards-at-age.*

-*Updated catch and stock weights-at-age.*

-*Re-estimated survey indices.*

The ASPM (see Appendices B1 and B2) was also modified to include:

1. Baranov catch equation instead of Pope's approximation.
2. Survey season: spring and autumn instead of begin and mid-year.
3. Survey variance: use input CV's and estimate additional variance, instead of estimate year-independent variance.
4. ϕ estimated instead of fixed at 0.2.
5. μ_{spawn}=0.25 instead of 0.1667.
6. Use age-dependent σ_a for CAA.
7. Flat commercial selectivity from age 6.
8. Commercial selectivity blocks (1963-1997, 1998-2011).

The updated ASPM (described above) is not the accepted model for this stock assessment. Rather the SARC56 panel accepted a model known as ASAP (described below).

In this updated assessment a statistical catch-at-age model (ASAP) was developed to estimate stock sizes and fishing mortalities. The reasons for selecting the ASAP model include: the ability to update the model *within the NEFSC and similar results to the ASPM. Based on ASAP, total SSB has ranged from 7,847mt to 34,399 mt during the assessment time period, with SSB in 2011 estimated at 26,877 mt (90% CI = 23,127 – 30,729 mt). Total January 1 biomass is estimated at 31,225 mt (90% CI =27,110 – 35,515 mt). Recent F's are near historic lows, with the 2011 fully recruited Ffull =0.13 (0.11 –0.16).*

A retrospective analysis for the 2004-2011 terminal years indicates small retrospective error in F and SSB with the tendency for the model to underestimate F and overestimate SSB. The F retrospective error ranged from -0.03 in 2010 to -0.24 in 2005. SSB retrospective error ranged from 0.03 in 2010 to 0.28 in 2005. Retrospective error in age 1 recruitment varied from -0.04 in 2007 to 1.56 in 2004.

An historical restrospective indicated that the stock status has been robust to the model type and data changes.

TOR 5. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

The existing reference points derived at GARM III from the ASPM for white hake are:

Fmsy proxy (= F40%) = 0.125 (on age 6)
SSBMSYPROXY = 56,300 mt
MSY = 5,800 mt

The new reference points derived at SARC56 based on the ASAP model for white hake are:

Fmsy proxy (= F40%) = 0.2 (on age 6)
SSBMSYPROXY = 32,400 mt
Overfished threshold = ½ *SSBMSYPROXY = 16,200 mt*
MSY = 5,630 mt

See the BRP section of this report for details about the decision to retain F40% as the F_{MSY} proxy.

TOR 6. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model developed for this peer review. In both cases, evaluate whether the stock is rebuilt.

a. If possible update the ASPM with new data and evaluate stock status (overfished and overfishing) with respect to the relevant BRP estimates.

The ASPM was updated with the new catch and survey data. Because of these data changes, the reference points from the GARM III ASPM are no longer valid for stock status determination.

b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

Based on the new ASAP model and BRPs recommended by the SARC56 panel, white hake is not overfished and overfishing is not occurring. Spawning stock biomass (SSB) in 2011 is *estimated to be 26,877 mt which is 83% of the revised SSBMSY proxy (32,400 mt). The 2011 fully selected fishing mortality is estimated to be 0.13 which is below (66% of) the revised FMSY proxy (0.20).*

TOR 7. Develop approaches and apply them to conduct stock projections and to compute the statistical distribution (e.g., the probability density function) of the OFL (overfishing level) and candidate ABCs.

a. Provide numerical annual projections (3-5 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).

Short term projections of future stock status were conducted based on the current assessment results without accounting for retrospective bias since the bias was very small. Two sets of recruitment assumptions were used, a long time series (1963-2009) and a short time series (1995-2009). Projections were run under two different F assumptions: FMSY(F40%) = 0.20, and F75%FMSY = 0.15.

b. Comment on which projections seem most realistic. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.

c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

Uncertainties that were not accounted for by assessment and reference point models were evaluated using model diagnostics. Standard model diagnostics (e.g., residual analyses, retrospective analyses) were used for model validation. A potential source of additional vulnerability is the slightly lower recruitment observed in the last fifteen years when compared with the entire time series. This was accounted for in the projections.

TOR 8. Evaluate the validity of the current stock definition, taking into account what is known about migration among stock areas. Make a recommendation about whether there is a need to modify the current stock definition for future stock assessments.

Information was presented on the distribution of white hake as well as any studies on spawning and larval patterns. Some genetic information exists on Canadian white hake, but does not extend into United States waters. It is likely that there is population structure within the current stock unit. But separate population units were not distinguished based on the information available.. For the purposes of this stock assessment, the current definition is appropriate with a small modification needed to account for different spatial coverage of the new survey vessel.

TOR 9. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in the most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

Thirteen previous research recommendations from SARC28 and SARC33 were evaluated. Most have either been addressed or shown to be no longer relevant. Some have been carried forward. A total of nine research recommendations are put forward which either have been combined from previous assessments or are new recommendations.

INTRODUCTION

The white hake, *Urophycis tenuis*, occurs from Newfoundland to Southern New England and is common on muddy bottom throughout the Gulf of Maine (Bigelow and Schroeder 1953; Collette and Klein-MacPhee 2002). Depth distribution of white hake varies by age and season; juveniles typically occupy shallower areas than adults, but individuals of all ages tend to move inshore or shoalward in summer, dispersing to deeper areas in winter (Musick 1974; Markel et al. 1982). Small white hake are difficult to distinguish from red hake, *Urophycis chuss*, likely resulting in a small degree of bias in reported nominal catches of white hake, with potentially red hake being landed as small white hake (Mayo and Terceiro 2005).

Larval distributions indicate the presence of two spawning groups in the Gulf of Maine-Georges Bank-Scotian Shelf region, one which spawns in deep water on the continental slope in late winter and early spring, and a second which spawns on the Scotian Shelf in the summer (Fahay and Able 1989; Lang et al. 1994). Since no spawning has been found to occur within the Gulf of Maine and at least two types of growth patterns are found in the otoliths of white hake in the GOM (Bohan and Burnett, pers. Comm.), the population found in U.S. waters appears to be supported by both spawning events, but spawning groups are not distinguishable in commercial landings. The stock is currently assessed as a single unit in United States waters, although Canadian catch from Georges Bank is included (Figure B1).

The current assessment summarizes all current information on the white hake stock and fishery through 2011. The white hake stock was last assessed and reviewed at the Groundfish Assessment Review Meeting (GARM III) in 2008 (NEFSC 2008). The data for this stock were reviewed at the AOP in 2013, but the model was not updated due to significant changes in the data. The assessment for this stock has evolved over time from index-based in the early 1990s, to a Collie-Sissenwine catch-index model in 1994, and then to an age-structured Virtual Population Analysis (VPA) in 1998. However, the addition of years to the VPA model created a marked retrospective pattern in the assessment in 2001. The assessment moved to a surplus production model which was itself unstable and rejected in 2002. The AIM (catch-index) method was then used to assess the status of the stock relative to biological reference points for the initial Groundfish Assessment Review Panel assessments (GARMs I and II; NEFSC 2002; Mayo and Terceiro 2005). The GARM III Review Panel recommended examining forward projecting length or age-based models to include all sizes of the stock, and suggested a forward projecting age-based model, but with more exploration of the model formulation to mitigate some of the problems encountered in the model. The final GARM III meeting ultimately accepted an Age-Structured Production Model (ASPM). The results of GARM III suggested the stock of white hake was overfished and overfishing was occurring (NEFSC 2008).

[SAW56 Editor's Note: The section headings in this white hake stock assessment report do not correspond directly to the stock assessment Terms of Reference (TORs). To assist readers, the SAW56 Editor has added "TOR #" in various places throughout the report to indicate sections that relate to particular TORs.]

STOCK STRUCTURE (TOR 8)

Little is known about the stock structure of white hake. Studies aimed at determining the existence of more than one stock tend to be confounded with the presence of red hake and the timing and location of sampling. Fahay and Able (1989) used several sources of data to attempt a solution to this problem. The evidence suggests that two groups of white hake exist in the Gulf of Maine-Georges Bank-Scotian Shelf region. The first group arises from a late winter-early spring spawning event which occurs in the deep water of the continental slope from the northeast Gulf of St. Lawrence to Southern New England. The second group spawns in the relatively shallow waters of the Scotian Shelf during the summer. No larvae were found in the Gulf of Maine itself and, therefore, it appears that the Gulf of Maine population is supported by the two spawning events described above. It may be that spawning occurred in the Gulf of Maine in the past (1920s and 1930s) but exploitation in that time period or a change in the environment eliminated some groups which would spawn on bottom structure in the winter (Ames 2012).

A study by Lang et al. (1994) supports the existence of a deep water spring spawning population that recruits to the estuaries in the Gulf of Maine. White hake first appeared as pelagic juveniles occurring in deep, offshore areas. Larger fish (50-80 mm) were found inshore later in the year as demersal juveniles. There was a northward progression of size and age from spring to summer, but no evidence of summer spawned fish recruiting to the Gulf of Maine estuaries was found. The timing of sampling suggests that the study may have missed these fish.

An age validation study (Bohan and Burnett, pers. comm.) revealed that three growth patterns may exist among Gulf of Maine - Southern New England white hake. The predominant pattern indicated winter-spring spawning event and accounted for over 90% of the samples. The second pattern showed a later spawning period because the fish were smaller in size at age and the size of the nucleus of the otolith was much smaller than the predominant pattern. This growth pattern occurred in fish from offshore strata 29, 30, and 36, closest to the Scotian Shelf. The third growth pattern was found in a limited number of white hake caught on the southern slope of Georges Bank. These had poorly defined annuli which made ageing impossible.

A genetic study conducted in Canadian waters concluded that there were three distinct genetic populations, Gulf of St. Lawrence, Grand Bank, and Scotian Shelf (Roy et al. 2012). However, these three genetic groups were caught in all three locations, so they are not spatially separate groups. No data were collected for fish in United States waters, so it is unknown whether the Scotian Shelf group would be separate from the Gulf of Maine. Given that some of the Gulf of Maine stock is supported by spawning on the Scotian Shelf, it is unlikely.

In light of the evidence above, all the white hake found in US waters were treated as one stock. Information from the Northeast Fisheries Science Center (NEFSC) spring and autumn bottom trawl surveys reveals that in the spring (during or just after spawning) white hake are located in deep water and are not found in inshore waters as often as in the autumn surveys (Figures B2 and B3). The fish may be spawning in deeper waters beyond the range of the survey coverage in the spring. Survey indices from various strata sets (Figures B4, B5 and B6) demonstrate that the Gulf of Maine area (Strata 26-30, 36-40) exhibits the same basic distribution pattern of abundance and biomass as the Georges Bank area (Strata 13-25), although the levels of abundance and biomass are quite different between areas. Southern New England (Strata 1-12) did not show the same abundance and biomass distribution pattern but this area (and all other areas, including the Mid-Atlantic (Strata 61-76) and inshore areas) contributes insignificantly to the total stock biomass (Figures B7 and B8). In previous assessments, offshore strata 33-35 were included in the strata setIt should be noted that these strata occur almost entirely in Canadian waters. In 1987, stratum 35 was split into two areas and only the southern area was sampled. In 2009, with the switch to the new survey vessel FRV H.B Bigelow, stratum 33 was discontinued due to the inability to effectively sample the irregular bathymetry of this stratum . To keep the strata set more consistent with the commercial landings, these were eliminated since the overall trend is similar (Figures B9 and B10). Therefore, for the purpose of the current assessment, landings from the Gulf of Maine and south (SA 464, 465, 511- 640) and the survey strata set from the Gulf of Maine to Northern Georges Bank

(21-30, 36-40) were used. This area accounted for over 95% of landings (Table B1) and around 85% of the whole survey swept-area biomass and 80% of the whole survey swept-area abundance.

THE FISHERY (TOR 1)

Commercial Landings

For this stock assessment the landings have been re-compiled and some changes have been made to the previous assessments (Burnett et al. (1984), NEFC (1986), NEFC (1991), NEFSC 1995, NEFSC 1999, NEFSC 2001, 2002, 2008, Mayo and Terceiro 2005). The first change is due to the inclusion of historical data collected by some states but not included in the NEFSC Weighout Database until later years. The data sources for the new landings by state are given in Table B2. The second difference is found between live pounds calculated using current conversion factors and the live pounds retrieved directly from the NEFSC Weighout Database in some years (Table B3). From 1975-1981 and 1985-1990, the market categories did not always have the correct conversion factor applied. All subsequent figures and tables use the calculated live weights.

Total landings of white hake decreased from 2,971 mt in 1964 to a low of 1,147 mt in 1967 (Table B4, Figure B11). Landings then gradually increased and peaked at 8,304 mt in 1985. Landings fluctuated around 5,000 to 6,000 mt until they peaked again in 1992 at 9,582 tons and declined slightly to 9,149 tons in 1993 (Table 4). Landings fell sharply to a 1997 level of 2,513 tons but increased moderately to 4,564 tons in 2003. Landings then declined to a low of 1,372 mt in 2008 followed by an increase in 2011 to 2,983 tons. The US has accounted for the major portion of landings with small amounts landed by Canada. Landings from other countries have been negligible since 1977.

The primary gear type used to catch white hake is the otter trawl, accounting for 37-83 per cent of the total United States landings (Table B5, Figure B12). Historically, line trawls and long-lines were also important, but from 1980 to 1990, this gear accounted for less than 5% of the total. This gear type again increased in importance and averaged 16% of the total landings between 1992 and 1998. Since then the landings from these gear types averaged less than 10 percent and are now less than one per cent of the total. Sink gill nets historically (1960s) accounted for less than 10% of total landings but the share increased in the 1970s to between 20 and 40% of the total.

The primary season for landing white hake is summer or quarter 3 (Table B6, Figure B13). The highest percentage of landings occurs in August, with the months of July, September and October each accounting for around 10% of the annual landings (Table B7). The percentages for September and October have declined slightly over time with the 1994-2011 average being less than the time series average (Table B7).

White hake landings occur primarily in the New England states of Maine and Massachusetts. Landings have been dominated by Maine with average landings between 35 and 70% of the total US landings between 1962 and 2007, however the percentage has declined to less than 20 through 2011 (Table B8, Figure B14). Massachusetts landings exceeded those of Maine from 1968 to 1974 but have accounted for 20 to 40% of the total landings from 1975-2005. Since 2006, Massachusetts landings of white hake have increased to over 80% in 2011. New Hampshire landings have been variable over time but have accounted for over 10 percent of the landings in some years (1980, 1999, and 2000). Other states contributing to landings are Connecticut, Rhode Island, New York, New Jersey, Delaware, Maryland, North Carolina and Virginia.

Under-tonnage vessels (less than 5 GRT) and unknown vessels (trips aggregated together) traditionally accounted for between 20 and 40% of US landings (Table B9). Since mandatory vessel trip reporting was implemented in 1994, these have become less important and have not been represented in the total landings except for a few years after the implementation of electronic dealer reporting in 2004. Tonnage classes 2 and 3 (5-50 GRT and 51-150 GRT, respectively) have accounted for the majority of the landings with tonnage class 3 dominating landings for the last twenty years. The landings of tonnage class 4 vessels (151-500 GRT) increased in importance in the 1980s and 1990s.

In 1986, a market category that combined red and white hake was created in some ports. In previous white hake assessments and the past red hake assessment, these landings were ignored. For this assessment, the landings of this market category were split between red and white hake based on the proportion of the commercial landings of the two species by statistical area (Table B10). These landings will be added to the total white hake landings.

Records of historical landings of white hake from the United States were discovered at ICNAF (1952) and (Table B11, Figure B15). These landings ranged from almost 22,000 mt in 1898 to 5,500 mt in 1950 with many years more than double the largest landings seen since 1964.

Distribution of Landings and Effort

Landings of white hake generally occur throughout the Gulf of Maine in the otter trawl fishery (Figures B16-B19). In the early part of the time series (1975-1980s), the highest concentration of landings appears to be in deeper waters, but this could also be due to more of the data in that time frame reported in quarter-degree squares and not to the current ten-minute square resolution of the maps. In the later part of the time series (2005 and later), there appear to be two areas, one in the western Gulf of Maine and the other towards the Hague Line (International Boundary) in the eastern Gulf of Maine (Figure B19). From 2008-2011, there has been an increase in landings in the Western Gulf of Maine (Figure B20). Landings from the sink gill net vessels generally are more inshore, although these data also suffer from the quarter-degree square reporting issue (Figures B21-B24). In the 1990s, there was an increase in landings in the eastern Gulf of Maine just north of Georges Bank (Figure B22). The later part of the time series does not show the same increase as the otter trawl landings (Figures B24-B25) until a small increase in 2011 (Figure B25).

Effort for otter trawl trips that caught white hake is concentrated in the deeper basins of the Gulf of Maine (Figures 26-29) and has declined over time. The effort has not increased over the last four years to the extent that the landings have (Figure B30). Effort for sink gill net trips is generally concentrated in the western GOM (Figures B31-B32). Reported effort over the last four years has been stable (Figure B33).

Recreational Catches

White hake recreational catches reported in the Marine Recreational Fishery Statistical Survey (MRFSS; now the Marine Recreational Information Program [MRIP]) since 1979 have generally been low, but have been summarized in Table B12. Since some of the recreational fishery takes place in January and February, which are not sampled by MRFSS/MRIP, the reported landings of white hake from the party/charter sector were summarized as well using Vessel Trip Report (VTR) data (Table B12).

Discards

Discard estimates were calculated in this assessment. The ratio-estimator used in this assessment is based on the methodology described in Rago et al. (2005) and updated in Wigley et al. (2007). It relies on a discard to kept (d/k) ratio where the kept component is defined as the total landings of all species within a 'fishery.' A fishery is defined as a homogeneous group of vessels with respect to gear type (longline, otter trawl, shrimp trawl, sink gill net, and scallop dredge), calendar quarter, and region (New England, Mid-Atlantic), and for otter trawls, mesh size (<= 5.49", > = 5.5 "). All trips were included if they occurred within this stratification regardless of whether or not they caught white hake.

The discard ratio for hakes in stratum h is the sum of discard weight over all observed trips divided by sum of kept weights over all observed trips:

$$\hat{R}_h = \frac{\sum_{i=1}^{n_h} d_{ih}}{\sum_{i=1}^{n_h} k_{ih}} \qquad (1)$$

where d_{ih} is the discards for hakes within trip i in stratum h and k_{ih} is the kept component of the catch for all species. R_h is the discard rate in stratum h. The stratum weighted discard to kept ratio is obtained by weighted sum of discard ratios over all strata:

$$\hat{R} = \sum_{h=1}^{H} \left(\frac{N_h}{\sum_{h=1}^{H} N_h} \right) \hat{R}_h \qquad (2)$$

The total discard within a strata is simply the product of the estimated discard ratio R and the total landings for the fishery, defined as stratum h, i.e., $D_h = R_h K_h$.

Values for cells with less than three trips were imputed using annual averages by gear type and region. To hind-cast the discards to 1964, discards/total landings by half year for the first three years (1989-1991 for otter trawl, sink gill net, and shrimp trawl; 1992-1994 for longline and scallop dredge) were averaged and the rate applied to the total landings from the dealer database. For the otter trawl fisheries, the mesh sizes were combined. Five-year average rates (1989-1993 and 1992-1996) were used to test the sensitivity of the estimates to the time period chosen for hind-casting. Discard mortality is assumed to be 100% given that white hake usually have everted (‘blown’) stomachs when they are caught.

The direct discard estimates range from 36 mt in 2007 to almost than 1,500 mt in 1993 (Table B13). The overall CV varied from 12.5% in 2011 to a high of 44% in 2003. The majority of the discards come from both the small and large mesh otter trawl fisheries (Tables B14-B16) with a few high estimates coming from the scallop dredge fisheries. The high values in 1989, 1990, 1993, and 1998 appear in the estimates regardless of the stratification scheme used (Figure B34) and may be related to good year classes. The hind-cast estimates using a three-year average are higher than the five-year average since the rates were higher in 1989 and 1990 than in 1992 (Figure B35).

Discards of white hake generally occur in the same locations as the kept portion of the catch on observed trips (Figures B36-B47). In the large-mesh otter trawl fishery (>= 5.5in mesh), there are some discards that occur in the Mid-Atlantic region, likely on summer flounder trips, in which few, if any, white hake are kept (Figures B36-39). The small-mesh otter trawl fishery occurs only in a few places in the Gulf of Maine and targets mainly silver hake and some squid (Figures B40-B43). In the Mid-Atlantic region, the targeted species are the two squid species, silver hake, scup, and black sea bass. These trips generally do not keep white hake. Most of the white hake caught on sink gill net trips is caught in the Gulf of Maine and not in the Mid-Atlantic (Figures B44-B47).

Total Catch

There was no hind-casting of the discards and foreign catch prior to 1964 (Figure B48). This would generally add another 20 percent to the total using an average proportion for the whole time series or 40% using the first 3-5 years of the time series. The White Hake Working Group (WHWG) decided that either assumption could be used but that neither was sufficiently reliable to put in place. Therefore the raw data were used in certain cases.

Species Composition of Catch

The GARM III Panel (NEFSC 2008) recommended using the ratio of white hake to red hake in the survey to split out white hake catch. This involved estimating red and white hake landings-at-length as well as red and white hake discards-at-length. These estimates were used for the GARM III white hake assessment. The method used has been further refined for the 2008 skate complex assessment (NEFSC 2009) and during the 2011 SAW 51 red hake assessment (NEFSC 2011). The red hake analysis required splitting the length samples for both species by the red hake stock areas to get red hake landings by stock area. The numbers of samples by area were minimal for red hake in the north and not adequate for white hake calculations in the south (Tables B16-B18). Because of this poor coverage and some resulting shifts in historical catches from red hake to white hake, the 2011 SAW 51 decided to use nominal catch for red hake. Therefore, nominal catches are also used for the current white hake assessment. The total catch for white hake is now generally less than that used in the 2008 GARM III assessment (Figure B49) except for the first few years of the time series. The WHWG decided that the catches from 1991-2011 were the best data because the discards were directly estimated and therefore should get a small coefficient of variation (CV) of 0.05 for modeling purposes. The catch from 1989-1991 had partially hind-cast discards and therefore the CV should be higher (0.08 was chosen). The CV on catch with completely hind-cast discards estimates was set at 0.15 while the first year of catch (1963) in which no hind-cast estimates were available was set to 0.25.

Length and Age Composition

Since the majority of white hake are landed in headed and gutted condition, length measurements have not generally been available from port samples. A regression developed to convert dorsal fin-caudal fin length to total length (Creaser and Lyons, 1985),has allowed measurements obtained from landed catch to be used to evaluate overall length composition since 1985. Age samples are still unavailable from port samples since otoliths are the structures used for ageing and are lost when the head is removed.

Commercial length composition during 1985-2011 was estimated by market category (pooling small and medium size categories together) from length frequency samples, pooled on a semiannual basis (Table B19). The sampling intensity overall has been adequate (< 300 mt/sample), except in 1989 and 1995 when only 13 and 12 samples were taken (350 mt/sample and 361 mt/sample). The sampling intensity in 1997 was very good (32 mt/sample), but the unclassified market category had only one sample for the entire year. In 1999 and 2000, there were no samples for the unclassified. The landings for this group were small so the landings were added at the end from 1998-2011. Since the landings of the red/white market category have never been sampled, the mesh size used to land white hake was examined (Table B20). On average, more landings come from small mesh than large mesh (Table B21). The WHWG also discussed whether large white hake would be landed in a mixed market category since these would obviously be white hake. Therefore, the decision was made to include the mixed red/white hake market category with the small/medium white hake market category.

Mean weights were obtained by applying the NEFSC semiannual survey length-weight equations using data from 1992-2012 to the semiannual market category length frequencies (Figure B50), as below:

ln Weight (kg, live) = -12.8621 + 3.2641*ln Length (cm) – Spring
ln Weight (kg, live) = -12.4856 + 3.1906*ln Length (cm) – Autumn

An examination was made of the annual estimates of the spring (Figure B51) and autumn (Figure B52) length-weight relationships, but there was no pattern and the WHWG decided to use a single equation for each season. Mean weight values were then divided into semiannual market category landings to derive estimated numbers landed by market category. These numbers were then summed over market categories and half-years to produce annual length compositions. Age-length keys were derived from NEFSC survey data for 1985-1988 and 2001-2011 (Table B22). Survey data for 1989-2000 were combined with data collected from observed trips. Age structures have been collected on observed trips from 2001-2011but not aged. The autumn survey for 2003 has not been aged and a pooled key using ages from 1982-2004 (without 2003 for fall) and 2011-2012 was used to fill in the year. The other years of survey data did not become available until after the pooled catch-at-age was computed. Commercial landings-at-age were derived by applying these age-length keys to the length composition. Estimates of US landings-at-age in numbers, weight, and mean weight at age are shown in Tables B23-Table25 and in Figure B53. Even with the addition of age data from the observer program, there is a great deal of imputation needed to fill in lengths with missing ages (Tables B26-B27). Most of the imputation occurs at the older ages (9 and 10+) which should have a minimal impact on the assessment.

The length composition of the otter trawl portion of the discards was characterized from the Fishery Observer Program (FOP) length samples by mesh size (Table B28-B29) because the length compositions of the two mesh sizes were different (Figure B54). The sampling in some years was poor to nonexistent and years were required to be pooled together (Table B30). The scallop dredge and shrimp trawl discards (Table B31) were added to the small-mesh otter trawl length composition based on the overall similarity between the length compositions of the gear types (Figure B54). The longline discards were combined with the large-mesh otter trawl discards. The sampling of discards from sink gill nets has not been adequate for characterizing that fleet sector (Table B29), but in looking at the overall length composition (Figure B55), the sink gill net discards were added to the total catch once the landings and discards were combined. The same age-length key used for commercial landings was used to derive the age composition shown in Table B32-Table B33and Figure B56. The amount of imputation needed for the discarded portion of the catch was less than for the landings-at-age since there are fewer old fish in the discards (Tales B35-B36, B40-B41). In a few years, the age zero fish were almost entirely imputed.

The two age compositions were combined to get a catch-at-age for 1989-2011 (Tables B37-B38, Figure B57). Since there are no length samples with which to characterize the recreational component of the fishery, and since the landings were very low, they were not included in the CAA. The mean weights at age do not show much of a trend over the time series, except a possible slight increase in the last three years (Table B39, Figure B58). The mean weight of age 9+ fish is very variable and is due to sparse sampling of the 9+ age classes.

STOCK ABUNDANCE AND BIOMASS INDICES (TOR 2)

Commercial LPUE

United States commercial LPUE (landings per unit effort in metric tons landed per day fished) indices for white hake were calculated for otter trawl trips that landed any white hake. Indices were also derived for trips that 'directed' toward white hake (white hake accounted for > 40%, 60% or 80% of the total landings for the trip, Table B42, Figures B59-B60). Directed trips at these different percentage levels have generally accounted for only 15%, 4% and 1% of the total white hake landings from otter trawls, and so may not provide a very meaningful index of stock abundance. The higher percentage directed trips (60% and 80% trips) also have years in which no trips met these criteria, so the WHWG decided to only use 40% trips as the cutoff for any standardization for directed trips. Total otter trawl LPUE indices were stable or increased through 1985, generally declined through 1997, and increased to a peak in 2003 (Figure B61). After a small decline through 2008, the indices increased to the highest value in the time series by 2011. The three directed LPUE indices generally show similar trends at the beginning of the time period, peaking in the late 1970s and declining through the 1990s (Figures B61-62). After 1996, the three indices all increase, however the magnitude of the subsequent increases after 1996 vary by index.

United States commercial LPUE indices for white hake were calculated for sink gill net trips that landed any white hake. Indices were also derived for trips that 'directed' toward white hake (white hake accounted for > 40%, 60% or 80% of the total landings for the trip, Table B43, Figures B63-B64). The higher percentage directed trips have generally accounted for 47%, 29% and 5% of the total white hake landings from sink gill nets, and so may not provide a very meaningful index of stock abundance. The higher percentage directed trips (60% and 80% trips) also have years in which no trips (or only one trip) met these criteria, so the WHWG decided to only use 40% trips as the cutoff for directed trips. The effort data for sink gill nets appears to be different between 1975-1993 and 1994-2011. The data collection system changed at that time and the way effort is calculated is likely not the same. Therefore, only data from 1994 onwards are used in the standardization. All four sink gill net LPUE indices generally decreased from 1975 through 1993 ((Figures B65-B66). They also increased from 1994-2003, generally declined through 2008, and increased through 2010. The three directed indices decline in 2011.

Fishing effort was standardized by applying a General Linear Model (GLM) to the LPUE data for all otter trawl trips and for the 40% directed trips. A four-factor model (year, calendar quarter, statistical area, tonnage class) was applied to both datasets and an additional model was applied to all trips which includes an area*year interaction term. These GLMs were applied to ln LPUE data derived for all otter trawl trips taking white hake from 1975 through 2011 (Tables B44 and B45). All of the main effects were highly significant. Standardized effort was calculated by multiplying the nominal effort in each cell by the product of the retransformed ln coefficients for each factor (excluding year). The estimated standardized effort was then summed over all categories to give annual totals (Tables B46 and B47). Trends in the two standardized LPUE series are similar to the trends in the two nominal LPUE indices (Figures B67 and B68). The standardized effort suggests that overall effort has declined since 1992 (Figure B67) while the directed effort was higher in the 1980s than in the 1990s and has recently increased (Figure B68).

Fishing effort was standardized by applying a General Linear Model to the LPUE data for all sink gill net trips. This GLM was applied to ln LPUE data derived for all sink gill net trips taking white hake from 1994 through 2011 (Tables B48). All of the main effects were highly significant. Standardized effort was calculated by multiplying the nominal effort in each cell by the product of the retransformed ln coefficients for each factor (excluding year). The estimated standardized effort was then summed over all categories to give annual totals (Tables B49). The standardized LPUE series is similar to the trend in the nominal LPUE indices (Figure B70). The standardized effort suggests that overall effort has declined since 2000 (Figure B70).

The distribution pattern of weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) in otter trawls has the highest LPUE values occurring in the northeast portion of the Gulf of Maine with lower values of LPUE to the west (Figures B71-B74). There has also been an increase from 2008-2011, in agreement with the LPUE indices (Figure B75). Sink gill net LPUE (Figures B76-B77) is higher in the southeast Gulf of Maine and there has also been a slight increase from 2008-2011 (Figure B78).

Research Vessel Abundance and Biomass Indices

The primary sources of biological information for white hake are the annual fishery independent surveys conducted by the Northeast Fisheries Science Center (NEFSC). The surveys are conducted using a random stratified sampling design which allocates samples relative to the size of the strata, defined by depth. The NEFSC has conducted both spring and fall bottom trawl surveys off the US continental shelf annually since 1963. The surveys extend from the Gulf of Maine to Cape Hatteras, NC, in offshore waters at depths 27-365 meters, and have been conducted in the fall since 1963 and in the spring since 1968. Details on the stratified random survey design and biological sampling methodology may be found in Azarovitz (1981) and Sosebee and Cadrin (2006). The area used for calculating abundance and biomass indices for white hake is the Gulf of Maine to Northern Georges Bank (offshore strata 21-30 and 36-40). Indices of abundance and biomass were calculated following the methods of Cochran (1977). Vessel (Delaware II vs. Albatross IV), door, and gear effects were not found to be significant for white hake (NEFC 1991). Other surveys used in the analysis of white hake are NEFSC shrimp survey (1985-2012), Massachusetts Division of Marine Fisheries (1978-2012), and Maine-New Hampshire (2000-2012) state surveys.

In 2009 the FRV *Henry B. Bigelow* replaced the R/V *Albatross IV* as the primary vessel for conducting spring and fall annual bottom trawl surveys for the NEFSC. There are many differences in the vessel operation, gear, and towing procedures between the new and old research platforms (NEFSC 2007). To merge survey information collected in 2009 onward with that collected previously, we need to be able to transform indices (perhaps at size and age) of abundance from the *Henry B. Bigelow* into those that would have been observed had the *Albatross IV* still been in service. Specifically we need to predict the relative abundance that would have been observed by the *Albatross IV* ($\hat{R}_A$) using the relative abundance from the *Henry B. Bigelow* (R_B) and a "calibration factor" (ρ),

(1) $\hat{R}_A = \rho R_B$

To provide information from which to estimate calibration factors for a broad range of species, 636 paired tows were conducted with the two vessels during 2008. Paired tows occurred at many stations in both the spring and fall surveys. Paired tows were also conducted during the summer and fall at non-random stations to improve the number of non-zero observations for some species. Protocols for the paired tows are described in NEFSC (2007).

The methodology for estimating the calibration factors was proposed by the NEFSC and reviewed by a panel of independent scientists in 2009. The reviewers considered calibration factors that could potentially be specific to either the spring or fall survey (Miller et al. 2010). They recommended using a calibration factor estimator based on a beta-binomial model for the data collected at each station for most species, but also recommended using a ratio-type estimator under certain circumstances and not attempting to estimate calibration factors for species that were not well sampled.

Since the 2009 review, it has become apparent that accounting for size of individuals can be necessary for many species. When there are different selectivity patterns for the two vessels, the fraction of available fish of a given size taken by the two gears is different. Therefore, the ratio of the mean catches by the two vessels will change with size. Under these circumstances, the estimated calibration factor that ignores size reflects an average ratio weighted across sizes where the weights of each size class are at least in part related to the number of individuals at that size and the number of stations where individuals at that size were caught. Applying calibration factors that ignore size effects to surveys conducted in subsequent years when the size composition is unchanged should not produce biased predictions (eq. 1). However, when the size composition changes, the frequency of individuals and number of stations where individuals are observed at each size changes and the implicit weighting across size classes used to obtain the estimated calibration factor will not apply to the new data. Consequently, the predicted numbers per tow that would have been caught by the *Albatross IV* will be biased.

For white hake, a suite of beta-binomial models were fit to the calibration data that made different assumptions on the relationship of the calibration factor to length. The models ranged from those that were constant with respect to length to logistic functions of length. The fitted logistic model with parameters constant across all stations had a sharp increase at about 7 cm (Model 4 in Table B50), but there were only 7 observations from 4 tows for fish less than 7 cm. For six of those observations only the *Albatross IV* caught fish and for the other only the *Henry B. Bigelow* caught fish. This resulted in substantial uncertainty of the calibration factor at those sizes with this model.

Although there were not sufficient numbers of ++ stations (i.e. non-zero catches from both vessels) in each of the spring and fall surveys to estimate seasonal effects, there is sufficient information in the site-specific stations and survey stations to split these groups. Doing so provided a very small decrease in the AIC in the constant calibration factor models (Model 2 vs. Model 1 inTable B50). There is a better fit of the model with different parameters for the spring and fall which is due primarily to the differences in dispersion parameters for the two seasons. The variability in the ratio between tows appears to be much less during the spring than the fall. However, there were only 26 ++ tows in the spring.

For the survey and site-specific data separately, there was no information to support the calibration factor changing with length. As such, the logistic models for those data (not shown) provided the same fit as the constant models. A logistic model fit to all data that forced a negative slope (Model 5 in Table B50, Figure B79) provided a poorer fit than the free logistic model that estimated the increasing slope at the smallest size. Finally, a fitted double logistic model that had both the positive and negative slopes of the two logistic models (not shown) converged but variance estimates were not available due to a non-positive hessian matrix at the maximized log-likelihood. Therefore, the WHWG decided to use the constant calibration estimated by Miller et al. (2010).

Spring stratified mean number and weight/tow indices declined from 1990 to 1997 and have slowly increased (Table B51, Figure B80). The autumn weight per tow index fluctuated around 5 kg/tow in the early 1960s and increased to approximately 12 kg/tow during the 1970s (Table B52, Figure B80). The autumn weight per tow index fluctuated around 10 kg/tow from 1983 to 1993. The index then declined to below 4 kg/tow in 1999, increased due to a moderately good year class. Following a decline through 2007, the index has since increased.

The mean, median and 95th percentile of length compositions from the spring survey have largely declined over the survey (Table B51, Figure B81). The maximum length has also followed this pattern. There was a period of increase in the 95th percentile and maximum during the late 1990s into the early 2000s, followed by a decline. Over the last three years, both have increased, but not to the same value as in the 1970s.

The mean of the length composition of the autumn survey has declined slightly from about 50 cm in the 1970s to just above 40 cm in the last decade (Table B52, Figure B82). The 95th percentile decreased from about 80 cm in the 1970s to 70 cm. The maximum length was stable at around 120 cm from the 1960s to the 1980s. In the 1990s and 2000s, the maximum has been around 105 cm. Length compositions of the spring and autumn surveys show the mode of the length composition is around 40 cm in all years and also show the decline of the larger fish (>= 100 cm) from the 1970s to later periods (Figure B83).

The Atlantic States Marine Fisheries Commission (ASMFC) conducts a summer shrimp survey in the Gulf of Maine. Finfish are also weighed and measured on these surveys and white hake are often caught. The biomass index from this survey shows a decline through 1997, an increase through 2002 and no trend since 2002 (Table B53, Figure B84). The mean length from the shrimp survey has been stable and the 95th percentile of length has increased over the time series (Figure B85). The length composition shows most fish caught are between 20 and 40 cm (Figure B86).

The Massachusetts Division of Marine Fisheries (MDMF) has also conducted spring and fall surveys since 1978 (Howe et al., 1981). The survey only covers a portion of the white hake stock area (Figure B87) but can still be useful, particularly for young fish. The spring survey shows a decline over the time series until about 1991 when it dropped to a low level and remained for most of the time series (Table B54, Figures B88-B91). There is a small increase at the end of the time series. The autumn series is more variable, particularly for abundance but has shown a similar decline (Table B55, Figures B88-B91). The length compositions from the spring survey show more fish less than 20 cm until 2003 when that size class disappeared (Figure B92). The autumn survey has the occasional large amount of small fish, but also has a larger number of 30-40 cm fish (Figure B93).

In 2000, a new survey was implemented in the state waters of Maine and New Hampshire (Figure B94, Sherman et al. 2011). Both the spring and autumn surveys show an increase through 2008 or 2009 followed by a decline (Table B56, Figure B95). The spring length composition shows mostly fish between 17 and 40 cm, with a potential strong year class in 2009 (Figure B96, likely Age 1 fish). The autumn length composition shows a similar grouping of fish, but there are signs of smaller fish (around 9-15 cm) in later years (Figure B97).

Research Vessel Age Compositions

The age data from the spring and fall surveys were used to age the NEFSC spring and fall surveys (by survey) using all available age data, even ages from outside the core area (Table B57) and the Massachusetts spring and fall surveys (by survey). If only the ages from the core area were used, there would be many more lengths without ages. For the years without age data, a pooled ALK was applied using 1982-2004 (without 2003 for fall) and 2011-2012 age data. The rest of the ages became available after the pooled key was created. The shrimp survey was not aged at this time. Length slicing was attempted to age the ME/NH survey.

The age compositions do not show many strong or poor year classes (Tables B58-B64, Figures B98-B99) although a few strong cohorts are prominent. There appears to be large 1984, 1989, 1990 and 1998 year classes in the fall survey data (Table B60). Some of the inability to follow year classes may be due to the amount of imputation involved in applying the annual keys (Tables B59, B61). Another reason may be that white hake are not easy to read and quality assurance/quality control tests indicate around 80% agreement between production ageing and quality control checks (http://www.nefsc.noaa.gov/fbp/QA-QC/data/whhk-results.html). The ME/NH spring survey was aged using length-slicing, but given the overlap with the lengths used for age 2 in the fall survey, this method may not work for the spring survey (Table B64). Either using the NEFSC survey to age the data collected in spring or waiting for the otoliths collected during the ME/NH survey to be aged would be more appropriate.

Research Vessel Distributions

In the spring, white hake are located in deeper waters of the Gulf of Maine and off the southern slope of Georges Bank (Figure B100). Over time the white hake located along the Mid-Atlantic slope have decreased. In the 1992, the white hake in the central GOM were reduced in number as well but have increased in the later time blocks, particularly 2008-2012 (Figure B100). Most white hake caught by the Massachusetts survey were in Cape Cod and Massachusetts Bays in the autumn (Figure B101). A few large tows were caught along the islands south of Cape Cod. These large tows were not found in the last time block (Figure B101). The largest tows in the ME/NH survey were located in the eastern portion of the survey in both time blocks for the springs survey (Figure B102). The fall survey is similar, with even less fish found near the Massachusetts border (Figure B103).

STOCK PARAMETERS

Natural Mortality

Natural mortality (M) for most gadid stocks is assumed to be 0.2. Hoenig (1983) developed an empirical relationship between total mortality (Z) and longevity (T_{max}):

$$\ln Z = 1.46 - 1.01 \ln T_{max}$$

Assuming a maximum age of 20 years for white hake (the oldest fish in the samples used in section on total mortality was 16 years and the maximum length in the commercial fishery data is much larger than this fish) this relationship estimates a Z of 0.2. In the absence of fishing mortality Z = M = 0.2.

Maturity

A logistic regression method (O'Brien et al. 1993) was used to fit maturity-at-age from the NEFSC spring survey data. In an attempt to smooth the noise in the data and increase sample sizes for those years with low sampling (Table B65), both 3-year and 5-year centered moving averages were applied (Figure B104).The WHWG examined the 3-year moving average, and determined that the estimated *A50* (the age at which 50% of fish are mature) varied about the time series average *A50*, but without any persistent trends. The WHWG decided to use a single time series average maturity ogive estimated from data in years 1982-2011. The time series *A50* for male white hake was 2.52 and 2.83 for females.

Pooled age-length key (TOR 3)

During the 2008 GARM III assessment review (NEFSC 2008), two differently configured Age Structured Assessment Program models (ASAP; NFT 2008) were presented that both had some diagnostic problems. The GARM III Panel chose the model with the shorter time series (1963-2007) and suggested further exploration of the model to improve the diagnostics. Some of the problems were with the starting conditions, for which the initial fishing mortality was estimated to be almost 3.0 (Figure B105). The recruitment pattern from the model had a large value in 1965 amongst some moderate values (Figure B105). Finally, in trying to get a model to converge, the catchability for the autumn survey had to be constrained, which then caused a residual pattern (Figure B106). Several attempts were made to fix these problems, including providing the model some age structure at the beginning of the time series by using a common ALK, which seemed a reasonable approach since there was already a common key used for the 2001-2007 commercial age data. All of the problems with the original model were minimized (Figures B107-B108). However, the GARM III Panel was not satisfied with the use of a common ALK for the survey years which had no age data. This was one reason why an alternative Age-Structured Production Model (ASPM; Butterworth et al. 2008) was chosen as the basis for the assessment. The GARM III Panel was concerned that estimates of recruitment would be dampened due to the use of a pooled key. The ASPM model did have a common key applied to the commercial length data for the recent years, but the reviewers concluded that there was no choice but to go with that model. This section evaluates the use of a pooled ALK on the results of various models.

The data from the 2008 GARM III ASPM model for white hake (Butterworth et al. 2008) have been re-evaluated in the current assessment using alternative models. Annual age data were available for the commercial catch from 1989-2000 and for survey data from 1982-2000. The catch at age was derived using semiannual age-length keys for 1989-2000. The spring survey age data were augmented with ages from January-June collected by the Northeast Fisheries Observer Program (NEFOP) while the autumn survey age data were augmented with ages from July-December collected by NEFOP. Two seasonal age-length keys were derived from these annual data and pooled across years. The spring and autumn survey numbers at age were derived using annual age-length keys for 1982-2000 for the appropriate survey. A second set of age matrices was developed using a single pooled age-length key for each survey. The percent difference between the two sets of age matrices was calculated.

Two different models have been used to determine whether the use of pooled age-length keys had a major effect on the 2008 GARM III assessments results. The first was a traditional Virtual Population Analysis (VPA) using the ADAPT calibration method (Parrack 1986, Gavaris 1986, and Conser and Powers 1990) as developed in the NOAA Fisheries Toolbox (NFT) ADAPT VPA version 2.7.7 (NFT 2007). The method assumes that the CAA is measured without error and requires data for each year of the analysis. The survey age data are treated as separate indices and only the spring ages 2-7 and autumn ages 1-6 (lagged forward to the beginning of the following year) were used in tuning. Ages 2-7 were estimated and the fishing mortality on the oldest true age was set equal to the Fs for ages 5-7.

The second model, using the Age-Structured Assessment Program (ASAP; NFT 2008), is a forward-projecting statistical catch at age model which assumes error in the CAA and does not require age or survey data for the entire time series (Legault and Restrepo 1999). The CV on the commercial landings was set at 0.01 for the entire time series. The effective sample size for the commercial fishery was set at the number of trips sampled for length composition. The survey age data were treated as proportions and multinomial error structure was assumed. Sample sizes were set at the number of non-zero tows for each survey. The weighting on recruitment was set to zero, which means that recruitment deviations from the Beverton-Holt Stock-Recruitment function were not included in the objective function. Selectivity was estimated by age for the fishery and the surveys, with selectivity set to one at age 5. These may not be the optimal settings for this stock, but they were held constant over the four model runs.

For both models, four separate configurations were examined: 1) using annual age-length keys for both commercial and surveys, 2) using annual ALK for commercial and pooled ALK for survey, 3) using pooled ALK for commercial and annual ALK for survey, and 4) using pooled ALK for both commercial and surveys.

Retrospective analyses, with one year at a time sequentially removed from the end of the data time series, were conducted on all eight model configurations to determine if pooling the ALKs improved or degraded the retrospective pattern. Given the short time series, the retrospective analyses were run back to 1994 and Mohn's rho (Mohn 1999) was calculated as the average of the relative differences between each "peel" from the final model run.

For each of the eight configurations, biological reference points were estimated following the recommendations of the 2008 GARM III Panel (NEFSC 2008) to examine whether stock status would be changed if pooled ALK were used. A yield-per-recruit analysis (Thompson and Bell 1934, NFT 2007b) was run to estimate fishing mortality at 40% SPR. The partial recruitment (i.e. selectivity) (PR) and mean weights at age were set using the last five years of data. The estimate of F40%, along with the same PR and mean weights, was then used in a 50-year projection using AGEPRO (Brodziak and Rago 1994; as developed in the NOAA Fisheries Toolbox; NFT 2010), to determine the biomass that would be achieved (BMSY proxy) in the long-term. The entire time series of recruitment values was used for the projection. ASAP also estimates reference points internally within the model runs using the biological data from the final year of the model and these were also compared.

When the pooled and unpooled age matrices are compared, most of the difference in the commercial

CAA mong the older age classes, while the spring and autumn surveys showed large differences at both young and older ages (Table B66).

The results of the VPA models show somewhat different results in fishing mortality and spawning stock biomass while the recruitment results are very similar (Figure B109). The converged part of the VPA (1989-1991) is the same across models, followed by divergence in both SSB and fishing mortality, suggesting that the older ages are the most variable among the ALKs (Table B67). However, all models pick up the same year classes, mainly the 1988, 1989 and 1998 year classes. The CVs on the stock sizes are the lowest for the pooled commercial data run, and highest for the pooled survey run. The highest CVs on the catchability coefficients are from different runs depending on the survey index.

The various ASAP model runs show more similarity to each other than the VPA runs (Figure B110). The trends in recruitment, SSB and fishing mortality are the same in the four model runs. The year classes in the ASAP runs are the same as in the VPA in addition to a bigger 1983 year class. Most of the terminal year estimates are similar across models (Table B68).

The retrospective analyses for the VPA models all show a very large retrospective bias for fishing mortality and spawning stock biomass (SSB) with a smaller bias for recruitment (Table B69, Figures B111-B116). Pooling the commercial ALKs reduces the bias in F and SSB while pooling the survey ALK increases that bias. For the model run with all the data sets pooled, the result is a reduction in Mohn's rho from using the unpooled data but slightly higher than the commercial only pooled. The bias for recruitment, while already low in the base model, is reduced slightly with more pooling of the data. The retrospective analyses for the ASAP models show a moderate bias in F and SSB but a much larger bias in recruitment (Table B69, Figures B117-B122). As more pooling is done, there is slightly more bias, but still within the range of a small retrospective pattern.

Biomass-based biological reference points from the VPA models are estimated to be between 59,600 mt and 61,200 mt (Table B70). The fishing mortality reference points are also estimated to very similar. While the terminal year estimates differ, the comparison between the reference points and the terminal year estimates indicates the same stock status regardless of the pooling of the data. The externally derived reference points from the ASAP models are also similar (SSB: 73,400 mt – 77,500 mt, F40: 0.2-0.22) and the resulting stock status the same. The difference between the ASAP and VPA derived reference points is largely driven by the slightly lower recruitment estimates in the VPA at the end of the time series (Figure B123). The internally derived reference points are lower (SSB: 38,800 mt-44,700 mt, F40: 0.15), but the stock status does not change.

The results presented in this section show that the results of the white hake stock assessment are more sensitive to the type of model chosen than the pooling of the data being used in the models. Given that the review panel was concerned about dampening of recruitment fluctuations, the results show that this was not an issue (Figure B123) and that the year class strength is very stable over the VPA and ASAP while the GARM III model had lower estimates overall. For white hake, which does not have a large variation in year class strengths, it does seem reasonable to use a pooled ALK when necessary. There is more work planned including the use of different years for the pooling exercise to determine if the years chosen influence the results. Simulation analyses are also needed to see if there are biases between a pooled ALK approach and fitting to length data using a single growth curve (derived from the same age data as the ALK).

ESTIMATES OF STOCK SIZE AND FISHING MORTALITY (TOR 4)

ASPM

The previous stock assessment was conducted using an Age-Structured Production Model (ASPM, now called Statistical Catch-at-Age [SCAA]; Butterworth and Rademeyer 2012). Since there have been substantial changes to the input data, it is important to separate the changes in the data before changing the model formulation or model type.

Spawning biomass, fishing proportion and recruitment trajectories are shown in Figure B124 for the following runs:

a. "2007": GARM III SCAA assessment,

With updated commercial data through 2007:
b. "2007 - new catches": as above, with updated annual catches,
c. "2007 - new catches + comm CAA": as above, with updated commercial catches-at-age,
d. "2007 - new catches + comm CAA + comm WAA": as above, with updated catch mean weight-at-age,

With updated survey data through 2007:
e. "2007 - new indices": GARM III SCAA assessment with updated NEFSC survey indices,
f. "2007 - new indices + CAA (same yr)": as above with updated survey catch-at-age data for the same years as used for the GARM III SCAA assessment,
g. "2007 - new indices + CAA": as above, but also including further years of survey catch-at-age data.

With all updated data through 2007:
h. "2007 - new data": all updated commercial and survey data,

With all updated data through 2011:
i. "2011 - new data": including data through 2011.

The major feature of these models is that the spawning biomasses estimated for the "2011 – new data" assessment are lower in absolute terms than their GARM III counterparts, with corresponding increases in estimates of fishing mortality and decreases in estimates of recruitment (Figures B124-127). This feature seems to arise primarily from the doming of the commercial selectivity now being estimated to be rather less than at the time of GARM III. The data changes having the most impact on the results are the modifications to the annual catches, followed by introducing catch-at-age information for additional years with an average ALK for years when age data were not available at the time of these model runs (Butterworth and Rademeyer 2012).

Further explorations of the SCAA were considered and are summarized in Appendix 1. A final run (RcpEvenNewer) was chosen to compare with the final ASAP run. This final run had three selectivity blocks (1963-1981, 1982-1997, and 1998-2011). The first selectivity block was based on using the results from a two-block model and moving the A50 one age younger.

ASAP

The use of ASAP (Age Structured Assessment Program v3.0.9, Legault and Restrepo 1999), which can be obtained from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/) was explored further from the work done at GARM III. In developing the base ASAP model configuration over 30 preliminary models configurations were explored. The WHWG eventually set up 3 basic ASAP models with different starting years based on the catch data that were agreed to be of better quality (1963) and with the start of catch age data and survey age data (1982 and 1989). The models used the commercial CAA (1+) from 1989-2011, the NEFSC spring survey abundance index (1+) and age composition (1-9+) from 1968-2011, and the autumn survey index (1+) and age composition (1-9+) from 1963-2011. To compare these models with the SCAA, a two-block commercial selectivity model was set up with the split in 1997/1998. Age at full selectivity was set at 6 for both periods. For initial runs selectivity at ages 7-9+ was allowed to be estimated but when upper bounds were hit at ages 7 and 8, selectivity was forced to be flat-topped. Selectivity for the survey was set to full at age 3 and all other ages were allowed to be freely estimated. The estimates of CV for the surveys were used in initial runs, but increased by 0.15 and 0.05 for the spring and autumn survey, respectively, using the results of the SCAA as a guide.

The effective sample sizes (ESS) for the age compositions were initially set at 50 for all three components from 1982 on and to half of that (25) for the years in which a pooled ALK was used. Two methods of adjusting these were applied. Following Francis (2011), adjustment in the effective sample sizes were informed by the overall fit between the predicted and observed mean age of the catch. However, this resulted in some very small ESS for the spring survey of 6 and 13 for the early and later time periods, respectively. Therefore, the WHWG decided to use the average of the estimated ESS for both the fishery and survey catch-at-age. The final Base model suggests that the ESS for the early survey age data should be higher, but since these were the years for which a pooled ALK was used to derive the age compositions, the WHWG decided not to adjust these values (Figures B128).

In the base runs, the WHWG noted that some of the CVs on the starting stock sizes were very large (Table B71). Therefore a prior was specified for the starting stock sizes so that they followed an exponential decline with a CV of 0.2.

Because the ASAP model run starting in 1963 estimated a higher fishing mortality at the start of the time series than the SCAA, a profile over different fixed values for F(1963) was run (Figure B129). The minimum objective function occurred for F(1963)= 0.3. These runs showed a large range in SSB and fishing mortality values (Figure B130) but recruitment values are relatively stable. There was also convergence of the SSB values after a period of about 10 years. When the starting F(1963) values within 4 points of the minimum objective function are examined, there is less variability in SSB and F (Figure B131). The same profile was run for the model starting in 1989 and these values fit in with the 1963 values (Figure B131). In contrast, the minimum for the SCAA model occurred for higher starting SSB values and a much lower starting F value, and the best estimates of this F value for each model were outside the 95% confidence intervals for the other. This difference was found to arise primarily from contributions to the objective function (negative log-likelihood) from the survey catch at age proportions in the earlier years. The WHWG decided that the consequent uncertainty in the early SSB values which are influential in the estimation of the parameters of a stock recruitment function, therefore did not allow for a stock-recruitment model to be used for reference point estimation at this time.

ASAP BASE model fits to the fishery catches were good, with no strong patterning of residuals over time and generally good agreement between modeled and observed catches (Figure B132). There were reasonable fits to the observed catch-at-age (Figure B133) with no large residual runs or obvious year class effects apparent in the residual patterning. Fishery selectivities show a higher selectivity at younger ages in the first block (Figure B134).

Fits to the NEFSC spring survey index exhibited no strong residual patterning (Figure B135) and the autumn survey fit fairly well, with the exception of the 1982 value which has never fit any model particularly well (Figure B136). There was some residual patterning to the index age composition fits (Figures B137-B138), with age 1 having a run of positive residuals starting around 2002 while age 3 during the same time period are negative. This pattern is stronger for the spring survey than for the fall. There was an age reader and otolith preparation change at that time. The selectivities estimated from the model indicate that the autumn survey catches more younger fish than the spring while the spring catches more older fish, although both surveys have highly domed selectivities (Figure B139)

The ASAP Base model configuration reflects the consensus opinion of the WHWG as the best model with which to evaluate stock status and provide catch advice. The assessment indicates that total SSB has ranged from 7,847 mt to 34,339 mt during the assessment time period, with current SSB in 2011 estimated at 26,877 mt (Table B72, Figure B140). Total biomass in 2011 is estimated at 31,225 mt and F's at the end of the time series are near historic lows (Figure B141) with the 2011 fully recruited, Ffull = 0.13. Fishing mortalities-at-age are presented in Table B73. The low fishing mortality on ages 1 through 3 is notable given that the maturity A50% is between ages 2 and 3. The current fishery selectivity allows one to two spawning events on average prior to entering the fishery. Until the last few years, recruitment over the past decade has been poor (Figure B142). Age-1 recruitment did not exceed 3 million fish between 2000 and 2004. Only three year classes in the time series have exceeded 10 million fish (Table B72). The current population structure is less reliant on fish that have not yet recruited to the fishery (fish age 1-3) than it was in the 1990s, with approximately 40% of the population age 4 and older compared to 20% previously (Table B74 and Figure B143).

MCMC was performed to characterize uncertainty in management quantities (SSB, F). An initial chain of length 200,000 was run with a thinning rate of 200 (resulting in 1000 saved iterations). Examining the trace and the autocorrelation suggested that the beginning of the chain was not well-mixed, and that additional thinning was needed (Appendix Figures B3.1, B3.2). These diagnostics were poorest for parameters at the beginning of the time series. To address this issue, a second chain of length 5 million was run with a thinning rate of 500 (resulting in 10,000 saved iterations). Examination of the trace from this longer chain suggested satisfactory mixing, however the autocorrelation suggested that additional thinning was still needed, particularly for parameters at the beginning of the time series (SSB1963, e.g.; Appendix Figures B3.3, B3.4). Subsequently, from the 10,000 iterations, the first 2000 were dropped (for burn-in) and the remaining 8,000 were thinned by a factor of 8, resulting in a total of 1000 iterations. All parameters had satisfactory diagnostics (Appendix Figures B3.5, B3.6).

In addition to characterizing uncertainty in parameter estimates, the MCMC analysis produces estimates of January 1 numbers at age for initializing projections. Because the diagnostics suggested that the initial chain (200,000) should have been longer, the distributions of numbers at age between that initial chain and the longer chain (after burn-in and further thinning) were compared (Appendix Figure B3.7). The distributions at age are virtually identical, suggesting that any correlation or lack of mixing in the initial chain did not impact the starting values for the projections. This result is not entirely surprising, given that the diagnostics suggested that the parameters at the beginning of the time series were less well-determined than those at the end of the time series.

The 90% probability intervals (PI) were calculated from the original MCMC analysis to provide a measure of uncertainty for the model point estimates. Time series plots of the 90% PIs for January-1Biomass, SSB and Ffull are shown in Figure B144. The distribution of values for the terminal year (2011) are shown in Figure B145 while the ASAP point estimates and the 90% PIs are reported below for the terminal year (2011):

ASAP point estimate for 2011 (90% probability interval)
SSB2011 (mt) 26,877 (23,127 – 30,729)
B2011 (mt) 31,225 (27,110 - 35,515)
Ffull 0.13 (0.11 – 0.16)

Retrospective analysis for the 2004-2011 terminal years indicates very little retrospective error in both F and SSB with the tendency for the model to underestimate F and overestimate SSB with mostly overestimation of recruitment (Figures B146-B148). The F retrospective error ranged from -0.03 in 2010 to -0.24 in 2005 (Table B75). SSB retrospective error ranged from 0.03 in 2010 to 0.28 in 2005. Retrospective error in age 1 recruitment varied from -0.04 in 2007 to 1.56 in 2004.

Sensitivities to the input data were conducted (Appendix B4). The first sensitivity run was to the length of the time series. When the time series starts in 1982, the results are not appreciably different (Appendix Figure B4.1) except that the SSB and recruitment values for the recent years are a little higher. The second sensitivity used a different strata set which included all offshore strata to calculate the survey indices (Appendix Figure B4.2). The differences in this sensiticity run are that the SSB values in the early part of the time series are higher while the recent SSB values are lower. The overall trend is similar.

BIOLOGICAL REFERENCE POINTS (TOR 5 and TOR 6)

Existing Reference Points

The existing reference points for white hake are:

*F*msy = 0.125 (on age 6)
SSBMSY = 56,300 mt
MSY = 5,800 mt

The existing ASPM model was updated, but the data have changed significantly and these reference points are no longer valid for stock status evaluation.

New Reference Points

Ideally the estimation of MSY-related reference points should be based on a fit of a stock-recruitment relationship for the population under consideration. In the case of this white hake stock however, this approach was not possible. Although a time series (1963-2011) of recruitment estimates can be determined with reasonable reliability, estimates of spawning biomass for the early years are sensitive to the different assumptions made in the assessment models evaluated by the WHWG. The consequence was that estimates of the stock recruitment relationship and associated MSY-related reference points ranged too widely to provide a reliable basis for advice. If the values to which a stock-recruitment relationship is to be fit are limited to more recent years that are not subject to this uncertainty in spawning biomass estimation, there is insufficient contrast in the data to allow the parameters of a stock recruitment relationship to be estimated with the necessary precision.

This situation necessitated the use of a proxy to determine F_{MSY} and related reference points. In the 2008 GARM III assessment the F40% SPR-based proxy had been used (NEFSC 2008). In considering the matter of recommending an F_{MSY} proxy on this basis, the WHWG noted that the suggestion of F40%, which has been widely used as this proxy, is based primarily on the work of Clark (1991, 1993). In the first of these papers, Clark considered a range of demographic and selectivity parameters, together with a number of stock recruitment relationships, and based upon deterministic evaluations recommended F35% as the proxy for F_{MSY}. In the second paper, Clark further introduced recruitment variability with ln recruitment residuals with a standard deviation σ_R of 0.6, and based his recommendation to use F40% rather than F35% on the criterion of little chance in forward projections, under a constant F value, that spawning biomass would drop below 20% of its deterministic pristine level (SSB0).

The WHWG decided to examine the application of Clark's approach to white hake in terms of a criterion of no more than a 5% probability (a value selected by the WHWG) that the population would drop below 0.2SSB0. The agreed ASAP assessment model provided values for the demographic and selectivity parameters. Three alternative plausible stock recruitment relationships were considered:

i) The standard basis used for projections of sampling recruitments randomly from the empirical cdf of recruitment estimates in the base case assessment (here ASAP from 1963 to 2011), with the caveat that if spawning biomass in the projections falls below the lowest value in the time series, the recruitment selected is multiplied by the ratio of the projected spawning biomass to the lowest in the series (i.e. corresponding deterministically to a hockey-stick stock-recruitment relationship). Projection under F=0 provided an estimate of median SSB0 from which the target 0.2SSB0 was obtained.

ii) A Beverton-Holt stock-recruitment relationship with steepness h=0.8, and σ_R=0.48 as determined from the ASAP time series of recruitments (with only the values from 1982 onwards being used to avoid the negative bias introduced in earlier estimates through smearing of year classes with the use of an average age-length key to provide the survey catches-at-age input to the assessment). Given a recent five year average of biological and selectivity parameters, relative reference points were calculated. Assuming that R_{MSY} corresponded to the average of the full time series of recruitment estimates, the relative reference points were scaled to calculate the pristine mean recruitment (R_0). Stochastic projections were then performed to determine SSB_{MSY} and SSB_0 (taken as the medians of the projected distributions).

iii) As for ii), except that steepness h=0.7.

The values of fully selected F each giving a probability of 5% of dropping below the corresponding 0.2SSB0 in any one year in each case (once the biomass spawning biomass distribution had stabilized) were: i) F=0.35, ii) F=0.25 and iii) F=0.22.

Based on the demographic and selectivity parameters of the white hake stock, the SPR based F reference points of F40% and F35% correspond respectively to fully selected F values of F=0.20 and F=0.24. Since the risk levels of these two reference points appeared to be similar, the WHWG recommended that F35% (i.e. a fully selected F=0.24) be adopted as the proxy for F_{MSY} as it allowed for higher yield.

Due to time constraints the WHWG interpolated the risk that spawning biomass would drop below 0.2*SSB0, associated with F=0.24 (F35%) for either steepness, to be slightly over 5%. During the course of the stock assessment peer review, the SARC reviewers requested that the lead analyst provide the actual probability at the F=0.24 value to compare the equivalence between the proposed F35% and F40% currently used for management (Table B76). In so doing, it was discovered that the probability under a steepness of 0.7 was actually 9.7% rather than the assumed 5%. Although the original calculations presented were correct, there turned out not to be a linear relationship between steepness and risk, so the 10% risk was unexpected (Figure B149). Since the WHWG had established 5% as the threshold for risk in comparing the F35% and F40%, and the value for F=0.24 exceeded that level, the SARC determined that the two options did not have equivalent risks, counter to what had been originally proposed. Based on that and other considerations, described in their reports and in NEFSC 2013, CRD 13-04, the reviewers decided not to recommend adopting F35%, but instead to retain F40% as the overfishing threshold proxy.

When the F_{MSY} proxy value of 0.2 is used in long-term projections the estimate of SSB_{MSY} is 32,400 mt (Figure B150). The estimate of SSB in 2011 is 26,877 mt and fishing mortality in 2011 is 0.13. Therefore, this assessment indicates that the stock of white hake is not overfished and overfishing is not occurring (Figure B151-Figure B153). Table B77 gives the existing and new (SARC56) reference points and shows the differences in the biological data which give rise to the differences in the reference points.

Short-Term Projections (TOR 7)

Projections were run at F_{MSY} proxy (0.2) and 75%$F_{MSY\ p}$roxy (0.15) from 2012 to 2016 using the numbers at age derived from the MCMC, two recruitment options, and assuming that catch in 2012 is 2900 mt (CFDERS value +100 mt for discards and Canadian catch) and are shown in Figures B154-157. The two recruitment options were drawing recruitment from an empirical cumulative distribution using the entire time series of estimates (1963-2009) and a shorter time series of recruitment estimates (1995-2009). The last two years (2010-2011) of the recruitment time series are uncertain and so were not used in the distribution. These results indicate that under 75%F_{MSY} proxy, the stock rebuilds by 2014 . If the short timer series is used, OFL in 2013 and 2014 are 5,457 mt and 5,574 mt (Table B78) while the TACs are 4,177 mt and 4,435 mt (Table B79). In 2013, the difference between the long and short time series of recruitment values for TACs is 4 mt.

Historical assessment retrospective

A comparison between the estimates of stock status for the current and the four previous assessments (SARC 33, GARM I, GARM II and GARM III) is provided in Figure B158. This historical "retrospective" examination of past model performance illustrates that the basic trends are the same for the alternative model, with biomass being above Bmsy in the 1970s and declining to below Bmsy in the 1990s. Even with the major changes in data that have occurred in the most recent update, the current assessment, in terms of relative biomass and fishing mortality, is entirely comparable with previous assessments. The scale differences between the current assessment and the previous GARM III assessment are driven by changes to the underlying catch data and not as a result of the assessment or choice of model (Figure B159).

SOURCES OF UNCERTAINTY

1. Possible mixture of red and white hake in early years of sea sample data may be the cause of high discard estimates in those years.

2. Lack of larger, older fish in survey age/length keys requires considerable augmentation of keys. This may affect mean weight of the plus group and SSB estimates.

3. White hake may move seasonally into and out of the defined stock area.

4. Catch at age information is not well characterized due to possible mis-identification of species in the commercial and sea sampling data, particularly in early years, low sampling of commercial landings in some years, and sparse discard data particularly in early years.

5. Catchability of older ages in the surveys is very low and is likely responsible for the uncertainty in starting numbers at age since there are no commercial catch-at-age data prior to 1989.

6. Mean weights at age in the catch for ages 5-9+ in 2001-2011 may not be well specified due to unaged observer samples.

RESEARCH RECOMMENDATIONS (TOR 9)

From SARC28

1. Investigate the potential utility of stratifying estimates of discard by mesh size in the otter trawl fishery data.
   - *The discard estimates are now stratified by mesh size.*

2. Incorporate all sources of catch in Catch at Age, including Canadian 4X landings and investigate feasibility of including discards throughout the 1985-present period.
   - *Discards have been incorporated into the model from 1963 with direct estimates from 1989. The current stock definition does not include 4X, although sensitivities were run at GARM III (see Stock Structure section for rationale). Recreational catch is not incorporated (see Data Section for rationale).*

3. Investigate stock structure and spawning patterns throughout the Gulf of Maine area, including relationships to areas in 4X and in deeper waters off Georges Bank and the Scotian Shelf.
   - *No new work has been carried out in the Gulf of Maine area. Some genetic analyses were conducted in Canadian waters (Roy et al. 2012).*

4. Further work on the 2-Bin Mass Balance Model should continue particularly as this relates to changes in catchability related to seasonal emigration of white hake during the autumn.
   - *This is no longer relevant because a full statistical catch at age model has been implemented.*

5. Investigate the availability and potential use of sea sample age samples to augment survey age/length keys.
   - *Sea sample ages are included in the ALKs from 1989-2000. The otolithes from 2001-2011 have not yet been aged.*

From SARC 33

1. Explore causes of retrospective pattern, if possible.
   - *This assessment does not have a large retrospective pattern.*

2. Improve species identification in sea sampling.
   - *Efforts are underway to improve training of at-sea observers.*

3. Increase sea sampling coverage for improved estimates of discard rates.
   - *Sea sampling coverage has been expanded.*

4. Expand NEFSC survey coverage into deeper water to better define stock distribution.
   - *Coverage has not been extended, however, with the new survey vessel, there are more tows conducted in deeper waters within the survey area from the southern flank of Georges Bank and south.*

5. Explore the use of 4X landings and Canadian survey data to define stock area.

· *The current stock definition does not include 4X, although sensitivities were run at GARM III.*

6. Continue the collection and ageing of samples from the ASMFC Shrimp survey.

· *Age samples have been collected from all ASMFC Shrimp surveys but have not been aged.*

7. For improved age-based analyses of commercial landings, continue ageing of sea sampling samples from 1991-1994.

· *Ages collected by the Observer Program are included in the ALKs from 1989-2000. The otoliths from 2001-2011 have not yet been aged.*

8. Explore alternative assessment methodology.

· *Three alternative models have been explored (SS2 (GARM III), ASPM (now referred to as SCAA) and ASAP).*

New Research Recommendations

- Further comparison of the SCAA and ASAP models. Perhaps institute a comparison using a simulated population and a common model configuration.
- Review of general SARC working group procedures which could for example include how new models are evaluated, the ability to modify models in real time, and policies for model testing prior to meetings using simulated data.
- Complete ageing of samples collected by the Observer program, the shrimp survey and state surveys (ME/NH survey)
- Continue production ageing of NEFSC Survey samples.
- Conduct sensitivity testing of the ASAP model using the shrimp and ME/NH survey indices.
- Further explore swept area biomass estimation for white hake.
- Develop improved calibration methods to adjust total fish length for fish with heads removed.
- Consider conducting cooperative research to collect intact fish from commercial gear.

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Table B1. Landings (mt, calc. live) of white hake by statistical area with percentages by statistical area (1) NAFO Sub Area 3, (2) Includes Sub Area 4, excluding 464-465, (3) Includes areas 500,510,520,531, 533,534, 536, 541, 542, 543 (4)Includes Sub Area 6 (5) Includes all area except those in notes (1) and (2).

		Statistical Areas																					
Year	Unknown (State waters)	3(1)	4(2)	464	465	511	512	513	514	515	521	522	525	526	537	538	539	561	562	5(3)	6(4)	Total Stock(5)	Total
1962	3178	0	0	0	0	12	0	71	0	0	0	0	0	0	0	0	0	0	0	0	0	3262	3262
1963	2163	0	231	9	29	150	2	128	303	135	240	331	1	1	1	0	0	64	6	0	0	3561	3792
1964	0	0	121	20	44	339	984	339	318	122	419	247	1	14	5	0	1	63	21	0	4	2942	3063
1965	0	0	110	2	9	164	1433	256	156	32	146	320	6	6	15	0	2	70	6	0	3	2625	2735
1966	0	0	62	2	25	36	758	212	116	12	146	158	4	11	23	0	2	58	6	1	2	1569	1631
1967	0	0	144	9	14	141	406	174	53	19	130	95	3	9	11	0	2	55	7	2	0	1131	1275
1968	0	0	66	6	6	97	332	263	76	11	199	98	9	15	17	1	5	63	8	3	4	1214	1280
1969	0	0	35	2	9	26	289	381	102	30	282	108	5	23	32	0	1	44	9	0	2	1347	1381
1970	0	0	46	12	17	21	276	589	190	114	274	179	7	32	42	0	3	46	6	0	5	1812	1859
1971	0	0	56	8	6	56	574	620	277	105	490	279	9	24	43	1	3	45	12	0	29	2580	2636
1972	0	0	70	3	13	62	829	850	314	99	390	222	21	17	18	0	2	49	44	0	18	2953	3023
1973	0	0	20	3	10	141	584	1009	472	189	449	164	6	24	44	0	2	21	11	0	42	3169	3189
1974	0	0	37	8	5	197	493	1567	550	182	525	178	3	13	7	0	3	18	21	0	42	3813	3850
1975	0	0	24	3	20	209	744	1614	262	254	370	123	5	6	4	0	3	22	18	0	32	3689	3714
1976	0	0	28	15	27	206	830	1822	272	392	404	96	6	5	4	0	1	9	15	0	24	4127	4156
1977	0	0	30	84	18	269	538	2428	531	384	350	303	10	5	5	1	0	35	20	0	11	4992	5022
1978	0	0	5	19	16	244	1345	1743	351	334	365	360	4	4	18	2	0	70	14	0	8	4896	4901
1979	0	0	0	14	2	655	957	1035	277	295	408	348	3	5	5	0	2	81	8	0	1	4096	4096
1980	0	0	0	29	22	584	821	1775	253	396	465	372	7	9	15	0	6	98	9	0	5	4868	4868
1981	0	0	0	64	121	59	1360	2258	149	669	306	488	10	8	14	0	1	355	52	3	66	5982	5982
1982	0	0	1	110	85	299	2056	1422	285	842	409	345	21	13	22	4	3	240	17	0	5	6177	6178
1983	0	0	3	52	189	427	1600	1464	264	1295	353	386	9	6	16	0	10	298	35	0	2	6405	6408
1984	0	0	3	50	224	354	1215	1716	319	1392	600	475	11	13	36	0	5	292	39	0	14	6753	6756
1985	0	19	0	10	61	425	1293	1642	439	2031	699	449	24	14	31	0	6	182	40	0	5	7351	7370
1986	0	278	5	56	120	648	1341	1103	261	1525	434	342	60	19	22	0	2	157	13	0	4	6107	6390
1987	0	8	2	44	30	345	965	1194	345	1479	574	509	17	26	33	1	5	206	38	0	5	5817	5828
1988	0	4	0	7	16	308	755	854	321	910	740	489	12	30	30	0	3	248	22	0	37	4782	4786
1989	0	6	0	26	7	209	1151	897	189	996	343	514	5	15	13	0	1	151	27	0	4	4549	4554
1990	0	2	0	82	58	242	1089	1031	210	1095	394	329	15	10	25	0	9	287	44	0	8	4929	4931
1991	0	0	0	21	2	191	1350	1138	247	1364	289	437	47	15	58	0	3	367	50	0	29	5607	5607
1992	0	0	0	6	0	416	1945	1595	285	2090	513	939	127	52	120	0	2	268	35	6	45	8444	8444
1993	0	0	0	0	0	222	1154	1064	221	1774	389	1839	211	38	78	0	4	393	45	0	32	7466	7466
1994	25	0	5	36	2	178	345	799	272	1313	375	576	462	34	57	2	7	155	10	0	83	4732	4737
1995	43	0	0	52	68	147	361	585	351	1457	377	510	127	57	49	17	11	67	10	3	32	4324	4324

1996	8	0	0	45	80	130	289	520	304	1065	350	323	28	28	29	0	5	34	2	0	40	3281	3281
1997	3	0	0	25	56	30	260	307	156	876	204	223	3	1	20	0	3	40	3	1	14	2223	2223
1998	16	0	0	23	47	65	196	206	180	911	291	252	55	5	38	3	1	53	6	2	17	2366	2366
1999	22	0	0	56	11	24	144	314	224	824	361	430	60	5	11	1	0	114	5	0	16	2621	2621
2000	25	0	0	45	36	50	179	455	254	1027	390	331	20	8	13	1	3	112	14	0	22	2984	2984
2001	19	0	0	33	45	82	284	563	183	1042	580	355	41	4	11	0	5	213	15	4	4	3482	3482
2002	14	0	0	40	57	69	301	575	238	929	514	323	25	11	6	1	7	120	32	0	5	3266	3266
2003	45	0	0	15	17	94	449	853	584	1498	411	286	15	4	14	0	4	123	17	1	2	4435	4435
2004	128	0	0	19	9	62	469	551	478	1126	333	176	17	0	11	3	5	71	26	0	26	3511	3511
2005	52	0	0	72	24	35	407	417	325	886	283	102	9	1	27	2	2	16	3	0	7	2670	2670

Table B1. cont.

Year	Unknown (State waters)	3(1)	4(2)	464	465	511	512	513	514	515	521	522	525	526	537	538	539	561	562	5(3)	6(4)	Total Stock(5)	Total
										Statistical Areas													
2006	41	0	0	10	27	4	237	243	195	569	231	103	3	3	12	0	3	3	1	0	15	1700	1700
2007	82	0	0	13	10	3	183	269	157	469	190	92	11	0	4	3	0	20	7	0	14	1529	1529
2008	42	0	0	34	3	2	131	261	208	362	142	79	13	0	7	0	0	29	5	0	13	1333	1333
2009	57	0	0	22	21	11	163	259	210	517	155	120	25	0	7	0	3	100	10	2	15	1696	1696
2010	9	0	0	31	11	7	73	283	343	468	284	173	23	0	10	0	0	67	18	0	8	1808	1808
2011	4	0	0	48	22	0	191	617	492	710	537	152	14	2	6	0	0	84	17	0	1	2897	2897

Table B1. cont.

Year	Unknown (state waters)	Statistical Areas 3[(1)]	4[(2)]	464	465	511	512	513	514	515	521	522	525	526	537	538	539	561	562	5[(3)]	6[(4)]
1964	0.00	0.00	3.96	0.64	1.44	11.07	32.12	11.07	10.37	4.00	13.70	8.06	0.03	0.47	0.15	0.00	0.04	2.06	0.70	0.00	0.12
1965	0.00	0.00	4.02	0.07	0.33	6.00	52.40	9.35	5.70	1.16	5.33	11.69	0.21	0.22	0.55	0.00	0.08	2.56	0.21	0.01	0.11
1966	0.00	0.00	3.79	0.11	1.53	2.18	46.44	12.98	7.09	0.72	8.94	9.67	0.23	0.69	1.39	0.00	0.13	3.57	0.36	0.05	0.13
1967	0.00	0.00	11.31	0.68	1.13	11.07	31.86	13.65	4.18	1.52	10.22	7.44	0.22	0.72	0.84	0.00	0.19	4.29	0.55	0.12	0.00
1968	0.00	0.00	5.18	0.50	0.50	7.55	25.98	20.53	5.94	0.86	15.56	7.62	0.71	1.20	1.34	0.06	0.43	4.90	0.61	0.27	0.30
1969	0.00	0.00	2.51	0.14	0.65	1.91	20.95	27.58	7.37	2.18	20.45	7.84	0.36	1.65	2.30	0.01	0.09	3.21	0.65	0.00	0.15
1970	0.00	0.00	2.50	0.63	0.89	1.11	14.85	31.70	10.20	6.13	14.72	9.65	0.38	1.72	2.28	0.02	0.14	2.47	0.33	0.00	0.28
1971	0.00	0.00	2.11	0.29	0.25	2.11	21.78	23.53	10.50	3.99	18.59	10.58	0.35	0.89	1.61	0.05	0.12	1.72	0.44	0.00	1.10
1972	0.00	0.00	2.30	0.08	0.44	2.06	27.43	28.13	10.39	3.28	12.89	7.35	0.71	0.58	0.59	0.00	0.08	1.64	1.44	0.01	0.60
1973	0.00	0.00	0.63	0.10	0.31	4.43	18.31	31.63	14.80	5.94	14.07	5.13	0.18	0.74	1.38	0.00	0.06	0.64	0.34	0.00	1.32
1974	0.00	0.00	0.96	0.20	0.13	5.13	12.81	40.70	14.30	4.73	13.63	4.63	0.08	0.35	0.17	0.00	0.08	0.47	0.54	0.00	1.09
1975	0.00	0.00	0.66	0.09	0.55	5.63	20.02	43.46	7.06	6.84	9.96	3.32	0.13	0.15	0.11	0.00	0.09	0.58	0.49	0.00	0.87
1976	0.00	0.00	0.69	0.37	0.65	4.97	19.96	43.83	6.55	9.44	9.72	2.30	0.14	0.13	0.10	0.01	0.01	0.22	0.35	0.00	0.57
1977	0.00	0.00	0.59	1.68	0.37	5.37	10.71	48.34	10.58	7.66	6.96	6.04	0.20	0.10	0.09	0.01	0.01	0.70	0.39	0.00	0.22
1978	0.00	0.00	0.10	0.39	0.33	4.97	27.44	35.56	7.15	6.82	7.45	7.34	0.07	0.08	0.37	0.03	0.01	1.43	0.29	0.00	0.17
1979	0.00	0.00	0.00	0.35	0.05	15.98	23.37	25.28	6.75	7.20	9.95	8.50	0.08	0.13	0.11	0.00	0.05	1.99	0.20	0.00	0.02
1980	0.00	0.00	0.00	0.61	0.44	12.01	16.86	36.47	5.19	8.13	9.56	7.65	0.15	0.19	0.30	0.01	0.12	2.02	0.19	0.00	0.11
1981	0.00	0.00	0.00	1.06	2.03	0.98	22.73	37.74	2.49	11.18	5.12	8.15	0.17	0.13	0.23	0.00	0.02	5.93	0.87	0.05	1.10
1982	0.00	0.00	0.01	1.78	1.37	4.84	33.27	23.02	4.62	13.62	6.62	5.59	0.34	0.20	0.36	0.07	0.05	3.89	0.28	0.00	0.07
1983	0.00	0.00	0.04	0.81	2.94	6.66	24.97	22.84	4.13	20.21	5.51	6.03	0.14	0.10	0.25	0.00	0.15	4.65	0.55	0.00	0.04
1984	0.00	0.00	0.05	0.73	3.31	5.24	17.98	25.40	4.72	20.61	8.88	7.03	0.16	0.20	0.53	0.01	0.07	4.32	0.58	0.00	0.20
1985	0.00	0.26	0.00	0.14	0.83	5.77	17.54	22.28	5.95	27.55	9.49	6.09	0.32	0.19	0.43	0.00	0.08	2.47	0.55	0.00	0.06
1986	0.00	4.35	0.07	0.87	1.88	10.15	20.99	17.26	4.09	23.87	6.80	5.36	0.94	0.30	0.34	0.00	0.03	2.46	0.20	0.00	0.06
1987	0.00	0.15	0.04	0.75	0.51	5.92	16.56	20.49	5.92	25.38	9.85	8.74	0.29	0.45	0.57	0.01	0.09	3.53	0.66	0.00	0.09
1988	0.00	0.09	0.00	0.14	0.33	6.43	15.77	17.85	6.72	19.01	15.45	10.23	0.25	0.63	0.62	0.00	0.07	5.17	0.47	0.00	0.77
1989	0.00	0.12	0.00	0.56	0.16	4.58	25.27	19.70	4.14	21.88	7.54	11.29	0.12	0.32	0.28	0.00	0.03	3.32	0.59	0.00	0.10
1990	0.00	0.04	0.00	1.67	1.17	4.91	22.09	20.91	4.26	22.21	7.99	6.68	0.30	0.20	0.50	0.00	0.18	5.83	0.89	0.00	0.17
1991	0.00	0.00	0.00	0.38	0.04	3.41	24.07	20.29	4.40	24.32	5.15	7.80	0.83	0.26	1.04	0.00	0.06	6.54	0.88	0.00	0.52
1992	0.00	0.00	0.00	0.07	0.00	4.93	23.04	18.90	3.37	24.75	6.07	11.12	1.50	0.61	1.42	0.00	0.03	3.17	0.41	0.07	0.54
1993	0.00	0.00	0.00	0.00	0.00	2.98	15.46	14.25	2.96	23.77	5.21	24.63	2.82	0.50	1.05	0.00	0.05	5.26	0.61	0.00	0.43
1994	0.52	0.00	0.10	0.76	0.05	3.77	7.33	16.96	5.76	27.87	7.95	12.23	9.80	0.73	1.22	0.05	0.15	3.29	0.21	0.01	1.75
1995	1.01	0.00	0.00	1.21	1.59	3.42	8.44	13.67	8.19	34.05	8.82	11.91	2.97	1.33	1.14	0.39	0.25	1.57	0.23	0.08	0.76
1996	0.24	0.00	0.00	1.38	2.45	3.96	8.84	15.89	9.30	32.55	10.70	9.87	0.84	0.86	0.88	0.00	0.14	1.05	0.06	0.01	1.21
1997	0.12	0.00	0.00	1.14	2.51	1.34	11.73	13.82	7.04	39.44	9.19	10.02	0.11	0.05	0.88	0.02	0.13	1.81	0.12	0.04	0.62
1998	0.69	0.00	0.00	0.96	1.98	2.78	8.34	8.77	7.67	38.76	12.38	10.71	2.32	0.22	1.61	0.13	0.05	2.26	0.27	0.07	0.71
1999	0.85	0.00	0.00	2.15	0.42	0.92	5.52	12.08	8.62	31.71	13.91	16.55	2.30	0.19	0.42	0.02	0.02	4.39	0.18	0.01	0.60
2000	0.82	0.00	0.00	1.51	1.23	1.69	6.07	15.37	8.58	34.72	13.19	11.19	0.67	0.25	0.44	0.03	0.09	3.79	0.46	0.00	0.73
2001	0.53	0.00	0.00	0.95	1.31	2.36	8.21	16.24	5.27	30.08	16.75	10.25	1.19	0.10	0.31	0.01	0.13	6.15	0.44	0.12	0.12
2002	0.43	0.00	0.00	1.24	1.74	2.11	9.25	17.69	7.30	28.56	15.79	9.93	0.77	0.33	0.19	0.02	0.21	3.70	1.00	0.01	0.16
2003	1.01	0.00	0.00	0.35	0.39	2.15	10.23	19.44	13.31	34.12	9.37	6.52	0.34	0.08	0.32	0.01	0.09	2.81	0.39	0.02	0.05
2004	3.65	0.00	0.00	0.55	0.26	1.83	13.87	16.30	14.13	33.28	9.86	5.20	0.51	0.01	0.31	0.09	0.15	2.11	0.78	0.00	0.77
2005	1.94	0.00	0.00	2.75	0.92	1.35	15.54	15.91	12.43	33.85	10.81	3.90	0.36	0.05	1.03	0.08	0.06	0.60	0.10	0.01	0.25

Table B1. cont.

Year	Unknown (state waters)	3[(1)]	4[(2)]	464	465	511	512	513	514	515	521	522	525	526	537	538	539	561	562	5[(3)]	6[(4)]
								Statistical Areas													
2006	2.42	0.00	0.00	0.62	1.64	0.27	14.29	14.63	11.73	34.28	13.91	6.22	0.19	0.16	0.72	0.02	0.19	0.18	0.06	0.00	0.89
2007	5.35	0.00	0.00	0.90	0.72	0.23	12.66	18.59	10.83	32.42	13.15	6.39	0.76	0.00	0.29	0.22	0.02	1.39	0.48	0.00	0.94
2008	3.19	0.00	0.00	2.65	0.26	0.14	10.18	20.25	16.13	28.05	10.98	6.12	1.00	0.01	0.56	0.02	0.04	2.27	0.36	0.00	0.98
2009	3.38	0.00	0.00	1.32	1.28	0.66	9.93	15.82	12.80	31.54	9.48	7.31	1.52	0.00	0.43	0.01	0.16	6.09	0.63	0.12	0.89
2010	0.47	0.00	0.00	1.71	0.60	0.37	4.08	15.75	19.04	26.01	15.77	9.61	1.28	0.03	0.57	0.01	0.01	3.71	1.01	0.00	0.43
2011	0.14	0.00	0.00	1.65	0.77	0.01	6.62	21.32	17.00	24.53	18.57	5.26	0.48	0.07	0.20	0.00	0.01	2.89	0.57	0.00	0.05
1964-2011 average	0.558	0.10	0.87	0.83	0.93	4.16	18.21	21.94	8.27	19.47	10.87	8.39	0.83	0.39	0.68	0.03	0.09	2.94	0.48	0.02	0.48
1994-2011 average	1.487	0.00	0.01	1.32	1.12	1.63	9.51	16.03	10.84	31.99	12.25	8.85	1.52	0.25	0.64	0.06	0.11	2.78	0.41	0.03	0.66

Table B2. Source of data for white hake by state and year from 1962-1988.

	CT	DE	ME	MD	MA	NH	NJ	NY	RI	VA
1962	gen can	gen can	gen can	gen can	gen can	gen can	gen can	gen can	gen can	gen can
1963	gen can	gen can	gen can	gen can	gen can	gen can	gen can	gen can	gen can	gen can
1964	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1965	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1966	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1967	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1968	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1969	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1970	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1971	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1972	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1973	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1974	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1975	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1976	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1977	gen can	gen can	**weighout**	gen can	**weighout**	gen can	gen can	gen can	**weighout**	gen can
1978	gen can	gen can	**weighout**	gen can	**weighout**	gen can	**weighout**	gen can	**weighout**	gen can
1979	gen can	gen can	**weighout**	gen can	**weighout**	gen can	**weighout**	gen can	**weighout**	gen can
1980	gen can	gen can	**weighout**	gen can	**weighout**	gen can	**weighout**	gen can	**weighout**	gen can
1981	gen can	gen can	**weighout**	gen can	**weighout**	**weighout**	**weighout**	gen can	**weighout**	gen can
1982	gen can	gen can	**weighout**	gen can	**weighout**	**weighout**	**weighout**	gen can	**weighout**	gen can
1983	gen can	gen can	**weighout**	gen can	**weighout**	**weighout**	**weighout**	gen can	**weighout**	**weighout**
1984	gen can	gen can	**weighout**	gen can	**weighout**	**weighout**	**weighout**	gen can	**weighout**	**weighout**
1985	gen can	gen can	**weighout**	gen can	**weighout**	**weighout**	**weighout**	gen can	**weighout**	**weighout**
1986	gen can	gen can	**weighout**	gen can	**weighout**	**weighout**	**weighout**	**weighout**	**weighout**	**weighout**
1987	gen can	gen can	**weighout**	gen can	**weighout**	**weighout**	**weighout**	**weighout**	**weighout**	**weighout**
1988	gen can	gen can	**weighout**	gen can	**weighout**	**weighout**	**weighout**	**weighout**	**weighout**	**weighout**

Table B3. US landings (mt, lnd[1]), live weight (mt, live[2]), and calculated live weight (mt, calc live[3]) of white hake by market category. Data are from WO and general canvas according to Table B2.

	Market Category																	
	Unclassified Dressed[4]			Small Round[5]			Small Gutted[6]			Unclassified Gutted[6]			Large Round[5]			Medium Round[5]		
	Lnd	Live	Calc. Live	Lnd	Live	Calc. Live	Lnd	Live	Calc. Live	Lnd	Live	Calc. Live	Lnd	Live	Calc. Live	Lnd	Live	Calc. Live
1962	2434	3262	3262															
1963	2830	3792	3792															
1964	28	37	37															
1965	24	32	32															
1966	24	33	33															
1967	16	22	22															
1968	16	21	21															
1969	9	12	12															
1970	13	17	17															
1971	25	34	34															
1972	22	29	29															
1973	2028	2717	2717															
1974	2873	3850	3850															
1975	2771	2823	3714															
1976	3101	3154	4156															
1977	3748	3812	5022															
1978	3657	3710	4900										1	1	1	0	0	0
1979	3057	3136	4096															
1980	3633	3761	4868															
1981	4459	5946	5976										3	3	3	1	1	1
1982	4317	5785	5785	13	17	13				8	10	9	4	4	4	2	2	2
1983	2935	3933	3933	1	2	1	2	3	2	7	10	8				1	1	1
1984	2428	3254	3254	8	10	8	4	5	4	38	50	43	0	0	0	0	0	0
1985	2783	2783	3729	3	3	3	15	20	17	54	72	61	1	1	1	1	1	1
1986	2780	2780	3725	0	0	0	0	0	0	22	28	25						
1987	1535	1536	2057	3	3	3				28	31	31	0	0	0	0	0	0
1988	554	738	743	3	3	3	3	3	3	40	46	46						
1989	814	1089	1091	1	1	1	0	0	0	8	9	9				2	2	2
1990	713	954	956	2	2	2	0	0	0	13	15	15	0	0	0			
1991	928	1244	1244	0	0	0				22	25	25	0	0	0	0	0	0
1992	1251	1677	1677	0	0	0	1	2	2	48	54	54	1	1	1	2	2	2
1993	1445	1936	1936	1	1	1	10	12	12	28	32	32	2	2	2	3	3	3
1994	913	1223	1223	0	0	0	0	0	0	26	30	30	0	0	0	34	34	34
1995	825	1106	1106				0	0	0	5	6	6	0	0	0	24	24	24
1996	554	742	742	0	0	0				3	4	4	1	1	1	2	2	2
1997	80	107	107	0	0	0	0	0	0	2	3	3	1	1	1	0	0	0
1998	69	93	93	0	0	0	0	0	0	3	3	3	0	0	0	0	0	0

Table B3. cont.

								Market Category										
		Unclassified Dressed[4]			Small Round[5]			Small Gutted[6]			Unclassified Gutted[6]			Large Round[5]			Medium Round[5]	
			Calc.			Calc.			Calc.			Calc.			Calc.			Calc.
	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live
1999	44	59	59	0	0	0	0	0	0	4	5	5	1	1	1	0	0	0
2000	36	48	48	0	0	0	0	0	0	3	3	3	1	1	1	0	0	0
2001	68	92	92				1	1	1	8	9	9	1	1	1	1	1	1
2002	29	39	39	0	0	0				3	4	4	1	1	1	0	0	0
2003	33	44	44	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
2004	163	219	219	4	4	4	13	15	15	13	15	15	35	35	35	38	38	38
2005	467	626	626	5	5	5	7	8	8	19	22	22	23	23	23	24	24	24
2006	250	335	335	7	7	7	7	8	8	8	9	9	205	205	205	26	26	26
2007	133	178	178	1	1	1	12	14	14	5	5	5	279	279	279	29	29	29
2008	44	59	59	2	2	2	16	18	18	9	10	10	267	267	267	42	42	42
2009	44	59	59	1	1	1	27	30	30	6	7	7	231	231	231	81	81	81
2010	56	74	74							0	0	0						
2011	45	60	60	0	0	0	24	27	27	47	53	53	7	7	7	1	1	1

[1] Data Source NEFSC Weighout Landed Pounds+General Canvas Landed Pounds as in Table 1.

[2] Data Source NEFSC Weighout Live Pounds+General Canvas Landed Pounds*Appropriate Conversion Factor as in Table 1.

[3] Data Source NEFSC Weighout Landed Pounds *Appropriate Conversion Factor+General Canvas Landed Pounds*Appropriate Conversion Factor as in Table 1.

[4] Conversion Factor = 1.34

[5] Conversion Factor = 1.00

[6] Conversion Factor = 1.13

Table B3. cont.

	Market Category														
	Large Dressed[4]			Medium Dressed[4]			Small Dressed[4]			Unclassified Round[5]			Total		
			Calc.			Calc.			Calc.			Calc.			Calc.
Year	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live
1962													2434	3262	3262
1963													2830	3792	3792
1964	1552	2079	2079	707	947	947							2286	3063	3063
1965	1533	2055	2055	484	648	648							2041	2734	2735
1966	790	1059	1059	403	540	540							1217	1631	1631
1967	511	685	685	424	569	569							951	1275	1275
1968	547	733	733	392	525	526							955	1280	1280
1969	594	796	796	428	573	574							1031	1381	1381
1970	772	1034	1034	603	807	807							1387	1859	1859
1971	1288	1726	1726	654	876	876							1967	2636	2636
1972	2045	2741	2741	189	253	253							2256	3023	3023
1973	283	379	379	70	93	93							2380	3189	3189
1974													2873	3850	3850
1975													2771	2823	3714
1976													3101	3154	4156
1977													3748	3812	5022
1978	0	0	0	0	0	0							3658	3712	4901
1979													3057	3136	4096
1980													3633	3761	4868
1981	2	3	3	0	0	0							4465	5953	5982
1982	185	248	248	9	12	12	79	106	106				4617	6184	6178
1983	1215	1628	1628	75	100	100	548	734	734				4784	6410	6408
1984	1851	2480	2480	137	183	183	585	784	784				5050	6768	6756
1985	1821	2440	2440	332	445	445	503	674	674				5512	6439	7370
1986	1460	1957	1957	212	284	284	297	398	398				4772	5447	6390
1987	1355	1816	1816	228	306	306	1204	1614	1614				4354	5307	5827
1988	1111	1489	1489	365	489	489	1503	2015	2015				3579	4782	4786
1989	1519	2035	2035	213	285	285	844	1131	1131				3401	4553	4554
1990	1031	1382	1382	466	625	625	1456	1951	1951				3683	4929	4931
1991	924	1238	1238	566	758	758	1748	2342	2342	0	0	0	4188	5607	5607
1992	1232	1650	1650	1064	1426	1426	2710	3631	3631	1	1	1	6310	8444	8444
1993	1387	1858	1858	1592	2133	2133	1110	1488	1488	2	2	2	5579	7466	7466
1994	1330	1782	1782	1009	1352	1352	236	317	317				3548	4737	4737
1995	1166	1562	1562	1018	1364	1364	183	245	245	18	18	18	3238	4324	4324
1996	919	1231	1231	819	1098	1097	135	181	181	23	23	23	2456	3281	3281
1997	794	1064	1064	560	751	751	220	294	294	4	4	4	1661	2223	2223
1998	1081	1448	1448	375	502	502	235	315	315	4	4	4	1767	2366	2366

Table B3 cont.

					Market Category										
		Large Dressed[4]			Medium Dressed[4]			Small Dressed[4]			Unclassified Round[5]			Total	
			Calc.			Calc.			Calc.			Calc.			Calc.
Year	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live	Lnd	Live	Live
1999	1237	1658	1658	432	579	579	236	316	316	2	2	2	1957	2621	2621
2000	1366	1831	1831	602	807	807	213	285	285	8	8	8	2230	2984	2984
2001	1522	2040	2040	608	815	815	391	524	524	0	0	0	2600	3481	3481
2002	1528	2047	2047	681	912	912	197	264	264	0	0	0	2438	3266	3266
2003	2778	3723	3723	400	536	536	95	127	127	1	1	1	3310	4435	4435
2004	1948	2611	2611	347	465	465	73	98	98	12	12	12	2647	3511	3511
2005	1073	1438	1438	317	425	425	67	89	89	10	10	10	2013	2670	2670
2006	602	807	807	181	242	242	39	53	53	10	10	10	1334	1701	1701
2007	511	685	685	160	215	215	63	85	85	38	38	38	1231	1529	1529
2008	406	544	544	205	274	274	84	112	112	4	4	4	1079	1333	1333
2009	595	797	797	249	333	333	114	153	153	4	4	4	1352	1697	1697
2010	850	1138	1138	334	448	448	110	147	147				1349	1808	1808
2011	1456	1951	1951	489	656	656	106	143	143	0	0	0	2175	2897	2897

[1] Data Source NEFSC Weighout Landed Pounds+General Canvas Landed Pounds as in Table 1.

[2] Data Source NEFSC Weighout Live Pounds+General Canvas Landed Pounds*Appropriate Conversion Factor as in Table 1.

[3] Data Source NEFSC Weighout Landed Pounds *Appropriate Conversion Factor+General Canvas Landed Pounds*Appropriate Conversion Factor as in Table 1.

[4] Conversion Factor = 1.34

[5] Conversion Factor = 1.00

[6] Conversion Factor = 1.13

Table B4. Total Landings (mt,calc live)[1] of white hake by country from the Gulf of Maine to Cape Hatteras (NAFO Subareas 5 and 6, and 464 and 465), 1964 2011.

		5Y[2]			5Z			6			Total		Grand
Year	Canada	USA[3]	Other[4]	Canada	USA	Other4	Canada	USA	Other4	Canada	USA	Other	Total
1964	3	2166		26	772			4		29	2942		2971
1965		2051			570			3			2625		2625
1966		1160			407			2			1569		1569
1967		819		16	312					16	1131		1147
1968	5	791		80	418			4		85	1214		1299
1969	4	840		30	505	6		2		34	1347	6	1387
1970	12	1218		34	590	222		5	58	46	1812	280	2138
1971	18	1646		82	905	109		29	105	100	2580	214	2894
1972	8	2171		32	764	159		18		40	2953	159	3152
1973	17	2408		100	719	1		42	4	117	3169	5	3291
1974	36	3003		196	768			42		232	3813		4045
1975	17	3106		129	551			32		146	3689		3835
1976		3564		195	539			24		195	4127		4322
1977		4253		170	728	189		11	149	170	4992		5500
1978	20	4051		135	837	1		8	28	155	4896	29	5080
1979	102	3235		149	860	3		1	1	251	4096	4	4351
1980	14	3881		291	982	1		5	1	305	4868	2	5175
1981	21	4680		433	1237			66		454	5982		6436
1982	352	5099		412	1074	1		5	1	764	6177	2	6943
1983	441	5290		369	1112			2		810	6405		7215
1984	479	5269		534	1471			14		1013	6753		7766
1985	452	5901		501	1446			5		953	7351		8304
1986	308	5054		648	1049			4		956	6107		7063
1987		4402		555	1410			5		555	5817		6372
1988		3171		534	1574			37		534	4782		5316
1989		3475		583	1070			4		583	4549		5132
1990		3808		547	1112			8		547	4929		5476
1991		4313		563	1265			29		563	5607		6170
1992		6338		1138	2061			45		1138	8444		9582
1993		4435		1683	2998			32		1683	7466		9149
1994		2970		957	1679			83		957	4732		5689

Table B4. Cont.

	5Y[2]			5Z			6			Total			Grand
Year	Canada	USA	Other[4]	Canada	USA	Other[3]	Canada	USA	Other[3]	Canada	USA	Other[3]	Total
1995		3064		481	1227			32		481	4324		4805
1996		2442		372	799			40		372	3281		3653
1997		1713		290	497			14		290	2223		2513
1998		1644		228	705			17		228	2366		2594
1999		1618		175	987			16		175	2621		2796
2000		2071		224	891			22		224	2984		3208
2001		2250		203	1228			4		203	3482		3685
2002		2222		158	1039			5		158	3266		3424
2003		3556		129	877			2		129	4435		4564
2004		2841		86	643			26		86	3511		3597
2005		2219		85	445			7		85	2670		2755
2006		1327		89	359			15		89	1700		1789
2007		1186		56	329			14		56	1529		1585
2008		1045		39	276			13		39	1333		1372
2009		1260		79	422			15		79	1696		1775
2010		1224		104	576			8		104	1808		1912
2011		2085		86	811			1		86	2897		2983

[1]Canada and Other as reported to ICNAF/NAFO for 1964-2011. USA Landings derived from NEFSC Weighout and General Canvas files.
[2]US 5Y landings include 464 and 465 and 5NK
[3]Includes Japan, Spain, and USSR.

Table B5. US commercial landings (mt,calc. live) and the annual percentage of total landings of white hake by gear type (NAFO Subareas 5 and 6, and 464 and 465), 1962-2011.

	Landings (mt,live)					Percentage of Annual Landings				
		Bottom	Sink				Bottom	Sink		
	Line	Otter	Gill	Other[1]		Line	Otter	Gill	Other[1]	
Year	Trawl	Trawl	Net	Gear	Total	Trawl	Trawl	Net	Gear	Total
1962	1585.3	1676.2	0.0	0.5	3262.1	48.6	51.4	0.0	0.0	100
1963	1800.7	1640.1	118.6	1.6	3561.0	50.6	46.1	3.3	0.0	100
1964	1155.4	1687.3	99.0	0.0	2941.7	39.3	57.4	3.4	0.0	100
1965	1515.7	1044.6	64.3	0.0	2624.5	57.8	39.8	2.4	0.0	100
1966	708.2	762.7	98.6	0.0	1569.4	45.1	48.6	6.3	0.0	100
1967	329.0	734.9	66.8	0.0	1130.6	29.1	65.0	5.9	0.0	100
1968	268.5	829.4	115.6	0.0	1213.5	22.1	68.3	9.5	0.0	100
1969	230.1	1013.7	102.7	0.0	1346.6	17.1	75.3	7.6	0.0	100
1970	204.8	1478.2	129.4	0.0	1812.4	11.3	81.6	7.1	0.0	100
1971	537.4	1921.6	117.7	3.3	2580.1	20.8	74.5	4.6	0.1	100
1972	836.9	1724.4	383.4	8.7	2953.4	28.3	58.4	13.0	0.3	100
1973	824.5	1833.6	505.3	5.9	3169.3	26.0	57.9	15.9	0.2	100
1974	646.5	1866.7	1298.8	0.8	3812.8	17.0	49.0	34.1	0.0	100
1975	989.5	1367.8	1331.9	0.1	3689.3	26.8	37.1	36.1	0.0	100
1976	547.2	1615.1	1964.2	0.8	4127.3	13.3	39.1	47.6	0.0	100
1977	373.3	2321.3	2290.3	7.4	4992.5	7.5	46.5	45.9	0.1	100
1978	317.4	2183.1	2377.4	18.2	4896.0	6.5	44.6	48.6	0.4	100
1979	209.9	2068.2	1802.5	15.5	4096.0	5.1	50.5	44.0	0.4	100
1980	100.4	2674.9	2065.5	27.6	4868.4	2.1	54.9	42.4	0.6	100
1981	110.7	3487.9	2376.3	7.2	5982.1	1.8	58.3	39.7	0.1	100
1982	99.0	3861.7	2201.0	15.8	6177.5	1.6	62.5	35.6	0.3	100
1983	83.1	4866.2	1394.2	61.4	6405.0	1.3	76.0	21.8	1.0	100
1984	33.3	5156.4	1485.9	77.6	6753.0	0.5	76.4	22.0	1.1	100
1985	318.2	5504.4	1417.1	111.7	7351.4	4.3	74.9	19.3	1.5	100
1986	231.9	4670.3	1161.9	43.1	6107.2	3.8	76.5	19.0	0.7	100
1987	86.2	4797.4	910.4	23.2	5817.3	1.5	82.5	15.7	0.4	100
1988	82.4	3655.2	1007.3	37.2	4782.1	1.7	76.4	21.1	0.8	100
1989	50.9	2548.4	1892.3	50.4	4542.0	1.1	56.1	41.7	1.1	100
1990	110.6	3279.8	1508.2	20.8	4919.5	2.2	66.7	30.7	0.4	100
1991	419.6	3547.7	1614.2	18.8	5600.3	7.5	63.3	28.8	0.3	100
1992	957.0	5190.6	2260.9	30.3	8438.9	11.3	61.5	26.8	0.4	100
1993	1207.1	4653.3	1588.4	12.6	7461.4	16.2	62.4	21.3	0.2	100
1994	1178.5	2478.4	1066.1	9.3	4732.3	24.9	52.4	22.5	0.2	100
1995	786.2	2405.7	1109.1	22.9	4323.9	18.2	55.6	25.7	0.5	100
1996	324.8	2036.8	916.0	3.6	3281.2	9.9	62.1	27.9	0.1	100
1997	414.4	1266.1	538.4	4.2	2223.0	18.6	57.0	24.2	0.2	100
1998	344.8	1285.6	730.7	4.9	2366.0	14.6	54.3	30.9	0.2	100
1999	144.0	1481.7	982.9	12.2	2620.8	5.5	56.5	37.5	0.5	100
2000	97.5	1811.0	1065.9	9.7	2984.0	3.3	60.7	35.7	0.3	100
2001	51.5	2421.3	1003.4	5.4	3481.5	1.5	69.5	28.8	0.2	100
2002	88.9	2338.5	823.2	15.6	3266.1	2.7	71.6	25.2	0.5	100
2003	104.3	2860.2	1417.2	52.8	4434.6	2.4	64.5	32.0	1.2	100
2004	63.8	2402.7	958.4	85.7	3510.6	1.8	68.4	27.3	2.4	100
2005	155.6	1883.8	573.3	57.7	2670.3	5.8	70.5	21.5	2.2	100
2006	30.0	1316.8	317.8	35.9	1700.5	1.8	77.4	18.7	2.1	100
2007	47.1	1031.8	392.9	56.7	1528.6	3.1	67.5	25.7	3.7	100
2008	9.0	904.4	399.8	19.6	1332.8	0.7	67.9	30.0	1.5	100
2009	5.9	1200.0	439.7	51.1	1696.6	0.3	70.7	25.9	3.0	100
2010	6.7	1387.9	403.5	9.6	1807.6	0.4	76.8	22.3	0.5	100
2011	7.6	2305.5	581.9	2.4	2897.4	0.3	79.6	20.1	0.1	100

[1] Includes Scottish seine, scallop dredge, Danish seine, pound net, floating trap net, lobster pots, fish pots, purse seine, common seine, diving gear, harpoon, rakes, and trammel net.

Table B6. Landings (mt,calc. live) of white hake by month, 1964-2011.

							Month							
Year	Unk.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1962	3262													3262
1963	3561													3561
1964	37	147	126	125	166	110	221	721	406	364	220	199	99	2942
1965	32	82	105	88	38	25	151	762	550	371	163	134	121	2625
1966	33	37	40	68	47	29	93	90	552	224	169	104	82	1569
1967	22	54	29	50	22	22	33	58	241	234	207	98	61	1131
1968	21	38	52	51	22	28	67	103	301	220	165	79	65	1214
1969	12	55	44	19	24	34	69	82	264	254	217	163	112	1347
1970	17	57	54	50	38	115	160	183	243	259	331	171	133	1812
1971	34	82	39	37	43	99	180	181	453	405	443	400	184	2580
1972	29	123	65	54	45	150	186	379	629	423	495	212	165	2953
1973	143	124	54	65	78	145	191	311	579	415	481	323	261	3169
1974	173	175	50	85	148	164	194	354	529	557	640	416	326	3813
1975	204	105	72	64	98	233	296	464	727	500	312	422	193	3689
1976	208	96	147	152	128	133	316	758	563	667	364	378	217	4127
1977	253	117	92	199	146	191	283	684	852	645	648	612	272	4992
1978	212	105	147	114	131	172	271	370	1084	859	761	480	190	4896
1979	314	102	34	78	106	232	322	642	964	433	379	308	182	4096
1980	502	109	108	106	102	131	441	720	860	636	553	405	195	4868
1981	66	196	86	126	116	129	437	903	1375	797	649	766	336	5982
1982	4	174	180	194	134	190	461	1139	1280	809	693	571	348	6177
1983	1	405	237	284	211	334	630	817	1015	745	744	577	406	6405
1984	9	425	228	221	208	341	537	770	1209	960	934	549	362	6753
1985	2	273	231	292	345	358	705	1097	1030	1114	825	633	445	7351
1986		309	276	288	386	392	619	999	851	723	623	369	272	6107
1987	3	135	188	221	163	270	724	1000	937	804	693	411	267	5817
1988	6	183	100	132	165	287	646	682	761	844	503	314	159	4782
1989	7	149	130	130	137	204	596	795	807	603	540	291	161	4549
1990	10	157	112	172	135	269	595	812	916	635	617	318	181	4929
1991	7	163	162	90	114	457	554	846	1126	871	624	345	247	5607
1992	5	277	247	294	283	344	832	1487	1756	1203	802	595	321	8444
1993	4	272	213	274	307	531	1000	1319	1232	790	744	514	266	7466

Table B6. cont.

							Month							
Year	Unk.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1994		143	275	198	325	348	615	688	717	447	462	293	221	4732
1995		140	180	190	138	261	504	705	597	504	565	366	175	4324
1996		135	149	152	100	243	376	366	553	448	402	235	122	3281
1997		97	116	73	73	62	209	271	344	343	285	206	143	2223
1998		67	92	116	107	101	257	319	308	322	275	213	191	2366
1999		151	141	156	142	181	346	377	330	288	209	175	125	2621
2000		125	160	195	192	294	296	371	358	257	344	222	171	2984
2001		209	205	200	228	259	309	441	373	324	348	300	286	3482
2002		298	301	316	234	173	228	313	324	302	272	241	263	3266
2003		365	289	459	267	465	381	470	457	365	358	311	248	4435
2004		277	354	377	213	236	341	364	393	286	212	219	238	3511
2005		253	303	259	130	193	285	241	301	208	175	176	148	2670
2006		206	215	190	87	67	113	168	153	119	132	127	125	1701
2007		120	104	109	65	101	181	191	175	137	143	120	81	1529
2008		92	93	88	57	39	110	183	175	128	134	138	95	1333
2009		134	122	155	101	91	133	174	169	164	186	176	93	1697
2010		180	184	223	122	126	141	137	138	145	156	118	137	1808
2011		215	313	311	263	167	178	220	258	278	234	206	255	2897

Table B7. The annual percentage of landings of white hake by month, 1964-2011.

						Percentage of total							
Year	Unk.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1964	1.3	5.0	4.3	4.2	5.7	3.7	7.5	24.5	13.8	12.4	7.5	6.8	3.4	100
1965	1.2	3.1	4.0	3.4	1.5	1.0	5.8	29.0	21.0	14.1	6.2	5.1	4.6	100
1966	2.1	2.3	2.5	4.3	3.0	1.9	6.0	5.7	35.2	14.3	10.8	6.6	5.2	100
1967	1.9	4.8	2.5	4.4	2.0	2.0	2.9	5.2	21.3	20.7	18.3	8.7	5.4	100
1968	1.8	3.1	4.3	4.2	1.9	2.3	5.5	8.5	24.8	18.2	13.6	6.5	5.4	100
1969	0.9	4.1	3.2	1.4	1.8	2.5	5.1	6.1	19.6	18.9	16.1	12.1	8.3	100
1970	0.9	3.1	3.0	2.8	2.1	6.4	8.8	10.1	13.4	14.3	18.3	9.4	7.3	100
1971	1.3	3.2	1.5	1.4	1.7	3.8	7.0	7.0	17.5	15.7	17.2	15.5	7.1	100
1972	1.0	4.2	2.2	1.8	1.5	5.1	6.3	12.8	21.3	14.3	16.8	7.2	5.6	100
1973	4.5	3.9	1.7	2.1	2.4	4.6	6.0	9.8	18.3	13.1	15.2	10.2	8.2	100
1974	4.5	4.6	1.3	2.2	3.9	4.3	5.1	9.3	13.9	14.6	16.8	10.9	8.6	100
1975	5.5	2.8	2.0	1.7	2.7	6.3	8.0	12.6	19.7	13.5	8.5	11.4	5.2	100
1976	5.0	2.3	3.6	3.7	3.1	3.2	7.7	18.4	13.7	16.2	8.8	9.2	5.3	100
1977	5.1	2.3	1.8	4.0	2.9	3.8	5.7	13.7	17.1	12.9	13.0	12.3	5.4	100
1978	4.3	2.1	3.0	2.3	2.7	3.5	5.5	7.6	22.1	17.6	15.5	9.8	3.9	100
1979	7.7	2.5	0.8	1.9	2.6	5.7	7.9	15.7	23.5	10.6	9.3	7.5	4.4	100
1980	10.3	2.2	2.2	2.2	2.1	2.7	9.1	14.8	17.7	13.1	11.4	8.3	4.0	100
1981	1.1	3.3	1.4	2.1	1.9	2.2	7.3	15.1	23.0	13.3	10.8	12.8	5.6	100
1982	0.1	2.8	2.9	3.1	2.2	3.1	7.5	18.4	20.7	13.1	11.2	9.2	5.6	100
1983	0.0	6.3	3.7	4.4	3.3	5.2	9.8	12.7	15.8	11.6	11.6	9.0	6.3	100
1984	0.1	6.3	3.4	3.3	3.1	5.1	7.9	11.4	17.9	14.2	13.8	8.1	5.4	100
1985	0.0	3.7	3.1	4.0	4.7	4.9	9.6	14.9	14.0	15.2	11.2	8.6	6.0	100
1986	0.0	5.1	4.5	4.7	6.3	6.4	10.1	16.4	13.9	11.8	10.2	6.0	4.5	100
1987	0.1	2.3	3.2	3.8	2.8	4.6	12.5	17.2	16.1	13.8	11.9	7.1	4.6	100
1988	0.1	3.8	2.1	2.8	3.4	6.0	13.5	14.3	15.9	17.7	10.5	6.6	3.3	100
1989	0.1	3.3	2.9	2.9	3.0	4.5	13.1	17.5	17.7	13.3	11.9	6.4	3.5	100
1990	0.2	3.2	2.3	3.5	2.7	5.5	12.1	16.5	18.6	12.9	12.5	6.5	3.7	100
1991	0.1	2.9	2.9	1.6	2.0	8.2	9.9	15.1	20.1	15.5	11.1	6.1	4.4	100
1992	0.1	3.3	2.9	3.5	3.4	4.1	9.8	17.6	20.8	14.2	9.5	7.0	3.8	100
1993	0.1	3.6	2.9	3.7	4.1	7.1	13.4	17.7	16.5	10.6	10.0	6.9	3.6	100
1994	0.0	3.0	5.8	4.2	6.9	7.3	13.0	14.5	15.2	9.5	9.8	6.2	4.7	100
1995	0.0	3.2	4.2	4.4	3.2	6.0	11.7	16.3	13.8	11.7	13.1	8.5	4.0	100

Table B7.cont.

Year	Unk.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
							Percentage of total							
1996	0.0	4.1	4.5	4.6	3.0	7.4	11.5	11.1	16.8	13.7	12.2	7.2	3.7	100
1997	0.0	4.4	5.2	3.3	3.3	2.8	9.4	12.2	15.5	15.4	12.8	9.3	6.5	100
1998	0.0	2.8	3.9	4.9	4.5	4.3	10.9	13.5	13.0	13.6	11.6	9.0	8.1	100
1999	0.0	5.8	5.4	6.0	5.4	6.9	13.2	14.4	12.6	11.0	8.0	6.7	4.8	100
2000	0.0	4.2	5.3	6.5	6.4	9.8	9.9	12.4	12.0	8.6	11.5	7.4	5.7	100
2001	0.0	6.0	5.9	5.7	6.6	7.4	8.9	12.7	10.7	9.3	10.0	8.6	8.2	100
2002	0.0	9.1	9.2	9.7	7.2	5.3	7.0	9.6	9.9	9.3	8.3	7.4	8.0	100
2003	0.0	8.2	6.5	10.3	6.0	10.5	8.6	10.6	10.3	8.2	8.1	7.0	5.6	100
2004	0.0	7.9	10.1	10.7	6.1	6.7	9.7	10.4	11.2	8.2	6.0	6.2	6.8	100
2005	0.0	9.5	11.3	9.7	4.9	7.2	10.7	9.0	11.3	7.8	6.5	6.6	5.5	100
2006	0.0	12.1	12.6	11.2	5.1	3.9	6.6	9.9	9.0	7.0	7.8	7.4	7.4	100
2007	0.0	7.8	6.8	7.1	4.3	6.6	11.9	12.5	11.4	9.0	9.4	7.9	5.3	100
2008	0.0	6.9	7.0	6.6	4.3	3.0	8.2	13.7	13.2	9.6	10.0	10.4	7.1	100
2009	0.0	7.9	7.2	9.1	6.0	5.4	7.8	10.2	9.9	9.7	10.9	10.3	5.5	100
2010	0.0	9.9	10.2	12.4	6.8	7.0	7.8	7.6	7.6	8.0	8.6	6.5	7.6	100
2011	0.0	7.4	10.8	10.7	9.1	5.8	6.1	7.6	8.9	9.6	8.1	7.1	8.8	100
average 1964-2011	1.3	4.7	4.5	4.8	3.9	5.1	8.7	13.0	16.2	12.7	11.3	8.3	5.6	100.0
average 1994-2011	0.0	6.7	7.3	7.6	5.5	6.3	9.6	11.6	11.8	9.9	9.6	7.8	6.3	100.0

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Table B8. Total US Landings (mt,calc.live) and the annual percentage of landings of white hake by state, 1962-2011.

					Landings (mt, live)									Percentage of total			
Year	CT	DE	Maine	MD	Mass.	NH	NJ	NY	RI	VA	NC	Total	Maine	Mass.	NH	RI	Others
1962	0.85		1817.15	0.06	1363.17	0.30	66.25	2.07	9.24	2.98		3262.07	55.7	41.8	0.0	0.3	2.2
1963	0.61		2163.25	0.06	1301.11	0.30	68.99	3.22	20.42	3.04		3561.00	60.7	36.5	0.0	0.6	2.1
1964			1522.15		1362.49	0.61	35.25	0.97	20.08	0.18		2941.74	51.7	46.3	0.0	0.7	1.2
1965	2.43		1743.32		830.08	0.91	27.29	0.49	19.20	0.79		2624.51	66.4	31.6	0.0	0.7	1.2
1966	2.31		914.04		596.63	0.73	29.48	0.18	26.03			1569.40	58.2	38.0	0.0	1.7	2.0
1967			638.17		453.00	0.61	20.97	0.18	17.71			1130.65	56.4	40.1	0.1	1.6	1.9
1968			568.08		576.09	1.09	18.60	1.58	48.08			1213.52	46.8	47.5	0.1	4.0	1.7
1969	1.09		474.45		818.01	1.22	6.32	2.98	42.51			1346.59	35.2	60.7	0.1	3.2	0.8
1970	0.06		638.66		1088.05	0.55	13.13	3.16	68.64	0.12		1812.36	35.2	60.0	0.0	3.8	0.9
1971	0.18		879.44		1563.73	1.22	26.20	5.53	102.96	0.85		2580.12	34.1	60.6	0.0	4.0	1.3
1972			1328.97		1537.89	2.43	22.49	3.83	57.72	0.06		2953.39	45.0	52.1	0.1	2.0	0.9
1973			1262.75		1699.26	103.82	37.32	1.88	64.29			3169.31	39.8	53.6	3.3	2.0	1.2
1974	0.18		1707.99		1900.65	134.03	35.07	4.19	30.71			3812.83	44.8	49.8	3.5	0.8	1.0
1975			2063.01		1404.54	172.26	29.91	1.64	17.90			3689.26	55.9	38.1	4.7	0.5	0.9
1976	3.53	0.49	2501.51		1401.73	182.47	16.90	4.13	16.56			4127.31	60.6	34.0	4.4	0.4	0.6
1977	1.52		2966.70		1738.29	240.15	9.24	1.88	34.68			4992.47	59.4	34.8	4.8	0.7	0.3
1978	1.09		3046.83		1617.77	207.39	4.35	3.71	14.90			4896.04	62.2	33.0	4.2	0.3	0.2
1979			2403.77		1366.03	313.03	0.75	1.03	11.38			4095.99	58.7	33.4	7.6	0.3	0.0
1980	0.55	3.04	2728.67		1593.46	498.29	3.74	0.30	40.34			4868.39	56.0	32.7	10.2	0.8	0.2
1981	60.78		3755.27		2023.82	100.64	2.53	4.92	34.11			5982.09	62.8	33.8	1.7	0.6	1.1
1982			4252.49		1793.81	76.97	1.01	4.13	49.07			6177.47	68.8	29.0	1.2	0.8	0.1
1983	0.18		4288.97		1870.79	204.23	0.97	0.97	38.69	0.16		6404.96	67.0	29.2	3.2	0.6	0.0
1984	0.30		3876.92		2442.50	313.89	0.56	8.81	110.05			6753.03	57.4	36.2	4.6	1.6	0.1
1985			3695.75		3367.97	162.40	0.80	2.43	122.06			7351.41	50.3	45.8	2.2	1.7	0.0
1986			2954.83		2872.36	189.24	2.91	2.12	85.74			6107.18	48.4	47.0	3.1	1.4	0.1
1987	3.04		3246.01		2253.23	184.74	2.11	5.32	122.81			5817.26	55.8	38.7	3.2	2.1	0.2
1988	6.32		2694.91		1897.79	48.04	40.33	2.23	92.47			4782.09	56.4	39.7	1.0	1.9	1.0
1989	3.16		3127.89		1325.93	49.03	6.85	0.78	40.75			4554.38	68.7	29.1	1.1	0.9	0.2
1990	5.57		2746.41		2109.09	0.69	9.10	0.20	59.99			4931.05	55.7	42.8	0.0	1.2	0.3
1991	3.10		3280.36		2122.07	70.00	5.92	11.82	113.99			5607.26	58.5	37.8	1.2	2.0	0.4
1992	2.65		5356.63		2520.91	287.04	28.79	8.05	239.59			8443.67	63.4	29.9	3.4	2.8	0.5

Table B8.cont.

					Landings (mt, live)								Percentage of total				
Year	CT	DE	Maine	MD	Mass.	NH	NJ	NY	RI	VA	NC	Total	Maine	Mass.	NH	RI	Others
1993	1.16		5041.54		2066.89	130.83	18.00	12.13	195.06			7465.60	67.5	27.7	1.8	2.6	0.4
1994			2938.54		1381.37	244.73	11.40	63.03	93.26			4732.33	62.1	29.2	5.2	2.0	1.6
1995	17.22		2531.77		1517.40	218.07	1.19	15.92	22.36	0.02		4323.94	58.6	35.1	5.0	0.5	0.8
1996	22.89		1949.45	0.12	1123.64	138.24	0.91	22.54	23.35	0.03		3281.16	59.4	34.2	4.2	0.7	1.4
1997	3.63		1427.29		620.48	129.09	0.03	18.68	23.80			2223.01	64.2	27.9	5.8	1.1	1.0
1998	3.99		1357.14		885.38	87.85	0.56	13.77	17.16	0.13	0.03	2366.01	57.4	37.4	3.7	0.7	0.8
1999	1.62		1351.32	0.01	941.27	285.80	0.85	14.43	25.50			2620.81	51.6	35.9	10.9	1.0	0.6
2000	7.01		1702.06		906.11	319.99	0.16	17.95	30.76	0.00		2984.05	57.0	30.4	10.7	1.0	0.8
2001	41.33		1899.32		1272.71	235.83	0.02	3.03	29.29	0.03		3481.55	54.6	36.6	6.8	0.8	1.3
2002	17.08		1964.77		1080.02	173.60		1.16	29.09	0.36		3266.07	60.2	33.1	5.3	0.9	0.6
2003	3.77		2909.78		1241.76	247.66	0.03	3.69	27.92			4434.60	65.6	28.0	5.6	0.6	0.2
2004	1.36		2160.90		1153.94	127.16	0.64	34.58	32.02	0.01		3510.60	61.6	32.9	3.6	0.9	1.0
2005	24.85		1523.78		966.82	122.64	0.07	22.86	9.31	0.00		2670.35	57.1	36.2	4.6	0.3	1.8
2006	9.31		758.83		832.05	68.31	0.44	20.75	10.81			1700.50	44.6	48.9	4.0	0.6	1.8
2007	3.59		598.46		842.48	46.75	1.00	26.31	10.03	0.02		1528.63	39.1	55.1	3.1	0.7	2.0
2008	1.12		357.71	0.01	917.04	19.65	0.17	30.10	6.97	0.05		1332.81	26.8	68.8	1.5	0.5	2.4
2009	0.79		351.70		1260.12	52.81	0.04	26.66	4.53			1696.64	20.7	74.3	3.1	0.3	1.6
2010	1.04		279.46	0.04	1467.03	48.21	3.77	6.77	1.30			1807.61	15.5	81.2	2.7	0.1	0.6
2011	0.49		395.53		2382.35	112.42	0.09	3.92	2.62	0.00		2897.42	13.7	82.2	3.9	0.1	0.2

Table B9. US Landings (mt,calc. live) and the annual percentage of total landings of white hake by tonnage class[1], 1962-2011.

	Tonnage Class (TC)					Percentage of total				
Year	2	3	4	Others[2]	Total	2	3	4	Others[2]	Total
1962	0	0	0	3262	3262	0.0	0.0	0.0	100.0	100
1963	0	0	0	3561	3561	0.0	0.0	0.0	100.0	100
1964	450	991	230	1271	2942	15.3	33.7	7.8	43.2	100
1965	312	510	198	1605	2625	11.9	19.4	7.5	61.2	100
1966	280	404	124	761	1569	17.8	25.7	7.9	48.5	100
1967	206	333	111	481	1131	18.2	29.4	9.8	42.5	100
1968	300	414	162	338	1214	24.7	34.1	13.3	27.9	100
1969	286	531	228	302	1347	21.3	39.5	16.9	22.4	100
1970	520	728	296	268	1812	28.7	40.2	16.3	14.8	100
1971	600	1084	341	555	2580	23.2	42.0	13.2	21.5	100
1972	738	972	303	941	2953	25.0	32.9	10.3	31.8	100
1973	934	913	287	1036	3169	29.5	28.8	9.1	32.7	100
1974	1334	884	338	1259	3814	35.0	23.2	8.9	33.0	100
1975	1302	602	254	1531	3689	35.3	16.3	6.9	41.5	100
1976	1587	837	279	1424	4127	38.5	20.3	6.8	34.5	100
1977	2363	1008	486	1136	4992	47.3	20.2	9.7	22.8	100
1978	2161	1083	534	1118	4896	44.1	22.1	10.9	22.8	100
1979	1687	1055	469	885	4096	41.2	25.8	11.5	21.6	100
1980	1809	1143	730	1187	4868	37.1	23.5	15.0	24.4	100
1981	2346	1492	1348	797	5982	39.2	24.9	22.5	13.3	100
1982	2626	1828	1309	415	6177	42.5	29.6	21.2	6.7	100
1983	1964	2403	1797	241	6405	30.7	37.5	28.1	3.8	100
1984	1966	2746	1621	420	6753	29.1	40.7	24.0	6.2	100
1985	1883	2987	2181	302	7351	25.6	40.6	29.7	4.1	100
1986	1190	2257	2195	465	6107	19.5	37.0	35.9	7.6	100
1987	1078	2517	1905	318	5817	18.5	43.3	32.8	5.5	100
1988	1114	1703	1732	233	4782	23.3	35.6	36.2	4.9	100
1989	1535	1495	1221	298	4549	33.7	32.9	26.8	6.6	100
1990	1330	1696	1702	202	4929	27.0	34.4	34.5	4.1	100
1991	1748	1895	1688	275	5607	31.2	33.8	30.1	4.9	100
1992	2665	2925	2362	491	8444	31.6	34.6	28.0	5.8	100
1993	1994	2563	2704	204	7466	26.7	34.3	36.2	2.7	100
1994	1345	1686	1693	9	4732	28.4	35.6	35.8	0.2	100
1995	1390	1563	1365	6	4324	32.2	36.1	31.6	0.1	100
1996	1218	1161	901	0	3281	37.1	35.4	27.5	0.0	100
1997	850	950	422	1	2223	38.2	42.7	19.0	0.0	100
1998	978	1007	378	4	2366	41.3	42.5	16.0	0.2	100
1999	1171	1019	430	0	2621	44.7	38.9	16.4	0.0	100
2000	1178	1179	628	0	2984	39.5	39.5	21.0	0.0	100
2001	1189	1539	754	0	3482	34.1	44.2	21.7	0.0	100
2002	1010	1557	700	0	3266	30.9	47.7	21.4	0.0	100
2003	1647	1855	932	0	4435	37.1	41.8	21.0	0.0	100
2004	1181	1532	788	10	3511	33.6	43.6	22.4	0.3	100
2005	609	1460	508	94	2670	22.8	54.7	19.0	3.5	100
2006	386	891	394	28	1700	22.7	52.4	23.2	1.7	100
2007	477	797	255	0	1529	31.2	52.1	16.7	0.0	100
2008	417	716	200	0	1333	31.3	53.7	15.0	0.0	100
2009	437	896	361	2	1697	25.8	52.8	21.3	0.1	100
2010	399	913	495	0	1808	22.1	50.5	27.4	0.0	100
2011	569	1474	844	10	2897	19.7	50.9	29.1	0.4	100

[1]TC2 = 5-50 GRT, TC3 = 51-150 GRT, TC4 = 151-500 GRT.
[2]Undertonnage and unknown vessels

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Table B10. Landings of red/white mixed market category. The percentage and mt assumed to be white hake using the ratio of white to white+red by statistical area are also given.

	1550	1551	1552	Total	% White Hake	mt White Hake
1986	76.3		152.2	228.5	87.9	200.8
1987	0.6		285.8	286.4	77.5	222.1
1988	25.9	280.6	347.2	653.7	82.1	536.7
1989	119.9	60.1	389.5	569.5	90.8	517.2
1990	22.5	67.7	160.5	250.7	85.7	214.9
1991	21.9	54.8	97.7	174.4	89.4	155.9
1992	8.5	30.7	35.9	75.1	87.6	65.8
1993	1.1	6.1	32.8	40	93.0	37.2
1994	0.5	50.6	49	100.1	92.5	92.6
1995	0.2	14	9.4	23.6	92.9	21.9
1996	0.8	17	2.6	20.4	73.2	14.9
1997	1.2	19.8	1.3	22.3	72.6	16.2
1998	0.1	17.5	0.1	17.7	21.0	3.7
1999	1.5	6.6	0.1	8.2	73.1	6.0
2000	1.6	14.3	0.6	16.5	86.9	14.3
2001	2.1	0.9	0.1	3.1	8.4	0.3
2002	0.8	0.8	0.8	2.4	70.3	1.7
2003	0.1	0.1		0.2	37.0	0.1
2004	12	3	0.3	15.3	78.3	12.0
2005	0	2.9	0.1	3	11.6	0.3
2006	3.1	1	0	4.1	72.2	3.0
2007	0.9	2.3		3.2	38.4	1.2
2008	2.1	39.1	0	41.2	18.9	7.8
2009	0.4	80.8	0.1	81.3	18.7	15.2
2010	0.9	67.7	0.1	68.7	17.8	12.2
2011	0	5.1		5.1	23.4	1.2

Table B11. Total Commercial Landings of white hake from 1893-2011.

	US White	Foreign White	White from Red/White	Total
1893	17424			17424
1894	17121			17121
1895	16227			16227
1896	14332			14332
1897	14239			14239
1898	21669			21669
1899	15275			15275
1900	11977			11977
1901	14090			14090
1902	19198			19198
1903	14927			14927
1904	17525			17525
1905	19039			19039
1906	14910			14910
1907	17134			17134
1908	19170			19170
1909	16177			16177
1910	17603			17603
1911	15548			15548
1912	14745			14745
1913	15788			15788
1914	13068			13068
1915	14623			14623
1916	14469			14469
1917	11003			11003
1918	10048			10048
1919	11862			11862
1920	9615			9615
1921	9787			9787
1922	10894			10894
1924	11214			11214
1925	10462			10462
1926	11177			11177
1927	10392			10392
1928	7798			7798
1929	10840			10840
1930	13976			13976
1931	6678			6678
1932	6991			6991
1933	6021			6021
1934	6214			6214
1935	10225			10225
1936	8947			8947
1937	9399			9399
1938	9384			9384
1939	8222			8222
1940	5982			5982
1941	5001			5001
1942	4985			4985
1943	7426			7426
1944	6155			6155
1945	5876			5876
1946	7398			7398
1947	6159			6159
1948	6660			6660
1949	6123			6123
1950	5492			5492
1951	5552			5552
1952	5429			5429
1953	4665			4665

1923 11222 11222 1954 3842 3842

Table B11. Cont.

	US White	Foreign White	White from Red/White	Total
1955	3529			3529
1956	2933			2933
1957	2606			2606
1958	2026			2026
1959	2372			2372
1960	2624			2624
1961	2365			2365
1962	3262			3262
1963	3561			3561
1964	2942	29		2971
1965	2625	0		2625
1966	1569	0		1569
1967	1131	16		1147
1968	1214	85		1299
1969	1347	40		1387
1970	1812	326		2138
1971	2580	314		2894
1972	2953	199		3152
1973	3169	122		3291
1974	3813	232		4045
1975	3689	146		3835
1976	4127	195		4322
1977	4992	508		5500
1978	4896	184		5080
1979	4096	255		4351
1980	4868	307		5175
1981	5982	454		6436
1982	6177	766		6943
1983	6405	810		7215

	US White	Foreign White	White from Red/White	Total
1986	6107	956	201	7264
1987	5817	555	222	6594
1988	4782	534	537	5853
1989	4549	583	517	5649
1990	4929	547	215	5691
1991	5607	563	156	6326
1992	8444	1138	66	9647
1993	7466	1683	37	9186
1994	4732	957	93	5782
1995	4324	481	22	4827
1996	3281	372	15	3668
1997	2223	290	16	2529
1998	2366	228	4	2598
1999	2621	175	6	2802
2000	2984	224	14	3222
2001	3482	203	0	3685
2002	3266	158	2	3426
2003	4435	129	0	4564
2004	3511	86	12	3609
2005	2670	85	0	2756
2006	1700	89	3	1792
2007	1529	56	1	1586
2008	1333	39	8	1380
2009	1696	79	15	1791
2010	1808	104	12	1924
2011	2897	86	1	2985

1984	6753	1013		7766
1985	7351	953		8304

Table B12. Recreational catches of white hake (number) from MRFSS (1981-2011), MRIP (2004-2011) and Vessel Trip Reports of For-Hire vessels (1995-2011).

	MRFSS			MRIP			VTR	
	NoAB1	mt AB1	no b2	NoAB1	mt AB1	no b2	No Kept	No Disc
1981	11,334	22.7	0					
1982	2,507	4.9	0					
1983	7,665	8.8	8,690					
1984	9,317	106.4	12,202					
1985	0	0.0	46					
1986	3,395	34.0	518					
1987	0	0.0	0					
1988	5,258	1.0	2650					
1989	2,457	2.2	3,800					
1990	209	0.2	322					
1991	88,728	82.2	42,295					
1992	0	0.0	0					
1993	295	0.2	0					
1994	393	0.6	555				1,899	242
1995	1,184	1.2	1,264				3,739	84
1996	839	0.9	386				2,388	266
1997	519	0.5	12				2,471	354
1998	2,453	0.7	254				912	313
1999	174	0.2	1,113				908	97
2000	341	0.3	3,280				2,595	312
2001	2,342	3.3	0				1,089	116
2002	5,488	10.7	1,940				1,728	214
2003	9,970	9.5	9,603				1,638	57
2004	3,491	11.3	299	1,888	9.8	277	1,630	31
2005	917	6.2	0	1,449	7.9	0	1,047	33
2006	1,237	7.9	174	688	3.8	175	877	29
2007	494	1.6	0	573	2.0	0	1,564	7
2008	3,240	11.0	11,999	4,067	19.8	7,583	1,370	37
2009	1,489	3.9	174	1,141	2.9	96	1,538	36
2010	2,277	6.1	1,309	1,602	4.7	793	2,170	22
2011	4,437	12.7	465	3,836	12.6	351	4,460	253

Table B13. Total Estimates of discards from 1963-2011. Estimates of the coefficient of variation (CV) are given for 1989-2011. Two estimates of hind-casted discards are given A. 3-year average by gear and B. 5-year average by gear type.

Year	3-Year	5-Year	Year	Discards	CV
1964	1453.7	1274.6	1989	1136.9	
1965	1425.7	1251.0	1990	1895.7	
1966	1323.2	1168.0	1991	392.6	23.2
1967	1177.6	1043.2	1992	766.9	37.4
1968	1147.4	1016.9	1993	1480.6	39.2
1969	1011.0	894.5	1994	309.5	27.3
1970	938.9	833.0	1995	294.7	30.9
1971	862.4	766.9	1996	216.9	13.6
1972	758.9	673.8	1997	136.5	20.2
1973	734.2	654.5	1998	149.2	24.4
1974	703.2	624.3	1999	939.5	21.0
1975	739.9	666.5	2000	216.0	23.3
1976	808.0	707.0	2001	354.7	21.4
1977	954.7	831.5	2002	123.0	18.1
1978	1152.0	984.2	2003	324.0	43.8
1979	1199.7	1036.3	2004	112.6	21.4
1980	1230.8	1085.9	2005	93.2	33.2
1981	1229.2	1077.7	2006	61.8	16.9
1982	1379.4	1213.4	2007	36.0	14.7
1983	1324.2	1156.8	2008	171.4	31.5
1984	1245.3	1097.9	2009	83.5	17.5
1985	1099.4	966.4	2010	90.6	15.5
1986	1142.1	995.7	2011	54.4	12.5
1987	1192.2	1016.6			
1988	1188.9	1002.8			

Table B14. Estimates of discards in the large and small mesh otter trawl fleets from the NEFOP from 1989-2011.

	OT	Large Mesh						OT	Small Mesh					
	Half 1		Half 2		Total			Half 1		Half 2		Total		
YEAR	trips	discards	trips	discards	trips	discards	CV	trips	discards	trips	discards	trips	discards	CV
1989	28	52.7	29	337.7	57	390.4	41.8	44	110.6	75	149.9	119	260.5	43.6
1990	26	358.1	28	114.5	54	472.6	78.1	41	271.2	43	530.0	84	801.2	47.7
1991	31	7.1	51	107.9	82	115.1	34.5	61	3.2	113	123.5	174	126.7	60.9
1992	64	49.8	18	262.6	82	312.4	74.2	52	192.9	52	9.8	104	202.7	80.2
1993	20	52.0	18	77.3	38	129.3	42.0	17	0.7	11	487.5	28	488.2	94.0
1994	26	80.8	15	15.0	41	95.8	60.5	2	77.7	20	103.1	22	180.8	33.6
1995	54	47.8	66	100.9	120	148.7	36.0	25	5.9	77	12.5	102	18.4	41.5
1996	30	22.3	25	0.3	55	22.6	49.1	36	99.5	91	18.3	127	117.8	9.7
1997	19	15.2	10	58.0	29	73.2	28.0	47	22.1	22	0.0	69	22.1	59.7
1998	18	18.9	6	33.4	24	52.3	42.1	13	0.0	18	0.0	31	0.0	
1999	6	3.3	31	127.9	37	131.1	52.5	20	0.5	32	751.0	52	751.5	24.5
2000	73	69.4	54	79.3	127	148.7	30.1	27	19.4	24	6.8	51	26.2	82.4
2001	61	83.0	135	164.5	196	247.5	27.4	36	48.3	36	0.0	72	48.3	39.6
2002	46	45.6	206	58.8	252	104.4	20.9	26	0.0	70	1.3	96	1.3	78.0
2003	196	33.9	200	33.5	396	67.4	29.4	65	0.7	75	238.7	140	239.4	58.6
2004	217	8.7	404	55.3	621	64.0	33.6	144	17.9	273	10.2	417	28.1	36.3
2005	666	6.4	763	14.4	1429	20.7	16.1	178	3.9	235	43.0	413	47.0	64.6
2006	405	9.8	269	23.7	674	33.5	23.4	122	4.6	103	0.6	225	5.2	38.5
2007	328	10.6	449	9.6	777	20.2	21.8	125	3.2	168	0.7	293	3.9	56.1
2008	412	5.7	469	13.3	881	19.0	18.2	105	86.2	106	31.7	211	117.9	45.5
2009	478	22.7	563	14.8	1041	37.5	30.9	198	0.5	304	20.1	502	20.5	35.0
2010	519	17.0	806	16.4	1325	33.4	13.4	305	11.8	289	1.3	594	13.1	66.4
2011	895	7.0	953	7.9	1848	14.9	12.3	252	7.2	302	0.4	554	7.6	80.1

Table B15. Estimates of discards in the sink gill net and longline fleets from the NEFOP from 1989-2011.

	SGN							Longline						
	Half 1		Half 2		Total			Half 1		Half 2		Total		
YEAR	trips	discards	trips	discards	trips	discards	CV	trips	discards	trips	discards	trips	discards	CV
1989	1	12.2	106	21.8	107	34.0	18.8							
1990	75	10.2	78	78.4	153	88.6	48.3							
1991	194	25.5	763	54.6	957	80.2	18.3	1	1.0	17	0.6	18	1.6	6.0
1992	497	37.3	690	84.0	1187	121.3	12.2	32	7.6		9.2	32	16.8	29.1
1993	348	56.4	422	153.7	770	210.1	20.0	3	3.2	1	2.1	4	5.2	34.4
1994	188	0.5	216	11.5	404	12.0	72.7	2	2.5		2.2	2	4.7	
1995	298	1.2	239	27.2	537	28.4	41.8	1	2.2		2.3	1	4.5	
1996	254	2.8	168	48.1	422	50.9	46.4		2.1		1.9		4.0	
1997	257	4.9	132	27.3	389	32.2	40.3		2.3		2.1		4.4	
1998	267	2.2	136	2.0	403	4.1	47.3		1.8	1	2.2	1	4.0	
1999	88	12.7	101	5.4	189	18.2	52.4		1.7		1.8		3.5	
2000	118	6.2	108	11.1	226	17.3	33.4		1.0		1.9		2.9	
2001	98	1.4	69	47.3	167	48.6	57.9		1.4		1.5		2.9	
2002	67	6.6	106	2.6	173	9.2	43.5		1.6	9	0.9	9	2.5	11.9
2003	162	6.4	330	7.7	492	14.2	30.0	17	0.1	2	0.1	19	0.2	
2004	289	1.0	800	10.6	1089	11.6	21.9	9	0.1	113	1.8	122	1.9	14.6
2005	260	3.9	744	14.2	1004	18.0	22.4	88	0.3	204	3.1	292	3.4	11.2
2006	136	2.0	115	13.0	251	14.9	43.0	46	0.1	56	3.3	102	3.4	25.1
2007	100	2.2	234	2.2	334	4.4	30.8	24	0.1	69	0.8	93	0.8	24.9
2008	115	4.2	194	10.1	309	14.3	27.8	27	0.1	52	2.5	79	2.7	20.1
2009	190	3.4	226	5.3	416	8.7	29.4	35	0.4	55	0.7	90	1.0	30.4
2010	419	16.5	1460	10.8	1879	27.3	32.1	72	0.2	120	2.0	192	2.2	21.9
2011	733	4.5	1326	19.2	2059	23.7	10.2	77	0.1	41	0.4	118	0.6	26.7

Table B16. Estimates of discards in the shrimp trawl and scallop dredge fleets from the NEFOP from 1989-2011.

	Shrimp							Scallop						
	Half 1		Half 2		Total			Half 1		Half 2		Total		
YEAR	trips	discards	trips	discards	trips	discards	CV	trips	discards	trips	discards	trips	discards	CV
1989	31	3.9	9	17.4	40	21.3	36.4							
1990	27	10.3	4	3.7	31	14.0	57.8							
1991	46	21.9	7	46.3	53	68.1	35.2		0.6	2	0.3	2	0.9	
1992	78	68.3	6	1.0	84	69.4	52.2	8	12.1	10	32.3	18	44.4	52.6
1993	78	4.7	4	0.5	82	5.2	36.5	14	8.1	8	634.5	22	642.6	54.2
1994	71	5.2	6	6.0	77	11.2	28.8	11	2.4	12	2.7	23	5.1	18.3
1995	64	11.3	9	1.0	73	12.3	16.6	15	52.3	12	30.2	27	82.5	87.5
1996	30	15.9	5	1.6	35	17.5	41.0	22	0.0	18	4.1	40	4.1	54.8
1997	17	2.3		0.3	17	2.6	24.7	19	0.1	10	2.0	29	2.2	44.4
1998		1.0		0.1		1.0		9	41.6	17	46.2	26	87.8	33.0
1999		0.4		0.0		0.4		15	14.1	56	20.6	71	34.7	39.7
2000		0.6		0.0		0.7		38	11.6	218	8.5	256	20.2	24.3
2001	3	0.0		0.0	3	0.0		58	3.2	48	4.2	106	7.4	13.0
2002		0.1	2	0.0	2	0.1		34	1.6	66	3.9	100	5.5	33.8
2003	15	0.2			15	0.2	86.9	50	0.4	74	2.3	124	2.7	35.6
2004	12	0.4	1	0.5	13	0.9	8.8	85	0.9	212	5.2	297	6.1	36.5
2005	17	0.4		0.0	17	0.4	48.0	128	0.3	206	3.2	334	3.6	85.7
2006	17	1.0	4	0.2	21	1.2	17.5	45	0.3	183	3.2	228	3.5	34.5
2007	14	3.6		0.6	14	4.2	23.3	158	0.6	202	2.0	360	2.6	46.6
2008	16	3.0	3	1.5	19	4.5	44.6	385	5.8	257	7.2	642	13.0	27.6
2009	7	2.9	5	2.1	12	5.0	37.5	373	7.4	117	3.3	490	10.7	38.4
2010	11	4.7	5	0.0	16	4.7	20.3	145	7.6	194	2.4	339	10.0	48.4
2011	1	5.6		0.1	1	5.7		177	0.2	216	1.7	393	2.0	30.1

Table B17. Summary of number of red hake measured by port samplers by region and half.

	North			South		
Year	1	2	Total	1	2	Total
1975					206	206
1976					103	103
1977				159		159
1979					94	94
1980				318		318
1981		101	101			
1982		431	431			
1983	125	1232	1357	182		182
1984	209	546	755	982	200	1182
1985	43	914	957	1139	599	1738
1986	335	1227	1562	948	320	1268
1987		967	967	786	213	999
1988	666	1172	1838	612	100	712
1989	111	410	521	201	309	510
1990	242	607	849	518	275	793
1991	826	214	1040	701	299	1000
1992		111	111	400	404	804
1993		95	95	303	100	403
1994				419	356	775
1995				1067	62	1129
1996					193	193
1997				1730	246	1976
1998		138	138	904	309	1213
1999		47	47	748	795	1543
2000				250	388	638
2001		99	99	1010	720	1730
2002				432	406	838
2003		345	345	1068	509	1577
2004		370	370	755	1195	1950
2005				1030	1208	2238
2006		93	93	1255	1146	2401
2007		37	37	2819	1758	4577
2008				2560	2183	4743
2009				1139	599	1738

Table B18. Summary of number of white hake measured by port samplers by market category and half in the northern region.

	Uncl			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985	101	397	498	356	640	996	509	790	1299
1986	215	398	613	686	668	1354	332	221	553
1987	245	237	482	443	998	1441	111	754	865
1988	100	41	141	1414	823	2237	233	299	532
1989	100	106	206	185	511	696		410	410
1990		101	101	613	749	1362	214	306	520
1991	207	94	301	674	1118	1792	474	728	1202
1992	97	237	334	1177	1423	2600	94	622	716
1993	214	293	507	1097	616	1713	361	851	1212
1994	236	697	933	397	1063	1460	303	667	970
1995	100		100	191	535	726	221	103	324
1996	199	546	745	101	976	1077	202	1210	1412
1997		58	58	1634	2455	4089	1166	1574	2740
1998		118	118	500	886	1386	897	1226	2123
1999				213	640	853	831	425	1256
2000				1172	1146	2318	229	336	565
2001				881	887	1768	784	1457	2241
2002				1171	1746	2917	1055	761	1816
2003				1637	1500	3137	1945	3285	5230
2004				988	978	1966	3536	1646	5182
2005	28	61	89	1203	1760	2963	1849	1711	3560
2006				1467	1936	3403	1922	1748	3670
2007				1524	1759	3283	1469	1489	2958
2008				1226	1857	3083	1698	1467	3165
2009				981	1691	2672	1248	1920	3168

Table B19. Summary of number of white hake measured by port samplers by market category and half in the southern region.

	Uncl			Small			Large		
Year	1	2	Total	1	2	Total	1	2	Total
1985									
1986									
1987	113		113						
1988				100		100			
1989									
1990				104		104			
1991				151		151			
1992				52	55	107	100		100
1993				50		50	100		100
1994									
1995									
1996									
1997									
1998				100		100			
1999					107	107		104	104
2000									
2001									
2002							85		85
2003				92	96	188			
2004				96		96			
2005	111		111	61		61	106		106
2006									
2007	201		201						
2008				142		142	5		5
2009					101	101	28		28

Table B20. Summary of US commercial white hake landings (mt), number of length samples (n), and number of fish measured (len) by market category and quarter from the Gulf of Maine to the Mid-Atlantic (SA 464,465, 511-515,521-526,533-539,611-626) for all gear types, 1985-2011.

	small					medium					large					unclassified					All	Sampling
	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Total	Intensity
1985 mt	129	162	235	167	694	63	78	181	124	446	237	433	1135	623	2428	367	737	1690	988	3782	7349	272
N		2	4	3	9					0		5	5	3	13		1	3	1	5	27	
# fish		233	323	317	873					0		632	519	271	1422		101	293	104	498	2793	
1986 mt	59	134	105	100	398	86	89	55	54	284	274	422	835	417	1948	455	752	1578	694	3478	6107	235
N	1	3	2	1	7	1	1		2	4	1	3	2	1	7	2	2	3	1	8	26	
# fish	102	263	215	101	681	94	122		229	445	122	315	248	96	781	215	206	292	106	819	2726	
1987 mt	98	300	641	576	1616	13	49	122	123	306	171	326	943	372	1813	262	482	1035	301	2080	5814	194
N		2	4	5	11		2	1	1	4		1	6	3	10	2	1	1	1	5	30	
# fish		240	291	507	1038		203	91	109	403		111	518	236	865	218	140	112	125	595	2901	
1988 mt	181	549	893	397	2020	26	82	262	120	489	136	330	695	325	1486	73	137	437	134	782	4776	165
N	5	6	3	5	19	1	1	1		3	1	1	2	1	5		1		1	2	29	
# fish	558	764	240	478	2040	100	92	105		297	112	121	214	85	532		100		41	141	3010	
1989 mt	149	221	404	358	1132	41	54	124	68	287	188	473	904	470	2035	33	190	774	96	1092	4547	350
N	1	1	2	2	6			1		1			2	2	4	1		1		2	13	
# fish	91	94	213	195	593			103		103			206	204	410	100		106		206	1312	
1990 mt	207	411	885	450	1953	43	108	303	171	625	167	300	596	320	1382	24	182	580	176	962	4922	234
N	3	4	4	2	13			2	1	3	2		1	1	4				1	1	21	
# fish	309	408	399	151	1267			202	99	301	214		101	103	418				101	101	2087	
1991 mt	150	366	1215	612	2342	88	160	381	129	758	126	241	533	338	1238	52	358	714	138	1262	5601	156
N	2	5	6	4	17	1	1	3	1	6	4	1	1	4	10		2	1		3	36	
# fish	151	471	485	244	1351	103	100	382	100	685	375	99	96	539	1109		207	94		301	3446	
1992 mt	424	626	1735	848	3633	102	202	766	358	1428	231	351	699	371	1651	60	280	1246	141	1727	8439	211
N	4	4	8	3	19	1	4	3	3	11		2	3	2	7	1		2		3	40	
# fish	329	432	655	240	1656	80	388	266	317	1051		194	325	297	816	97		237		334	3857	
1993 mt	331	502	453	214	1500	161	397	1117	461	2136	173	476	795	416	1860	94	463	975	433	1965	7462	191
N	2	5	4	1	12	2	3	2	1	8	2	3	7	2	14		2	2	1	5	39	
# fish	150	504	275	50	979	184	309	196	95	784	199	262	676	175	1312		214	196	97	507	3582	
1994 mt	63	82	116	56	317	154	374	593	265	1386	206	481	687	407	1782	193	352	457	251	1252	4737	144
N		2	4	1	7		2	3	3	8		3	4	2	9		2	4	3	9	33	
# fish		167	386	100	653		230	305	272	807		303	363	304	970		236	431	372	1039	3469	
1995 mt	39	43	98	66	245	140	238	616	399	1393	197	398	595	374	1564	134	225	504	268	1130	4333	361
N		1	1	1	3		2	2	1	5		2		1	3		1			1	12	
# fish		107	97	105	309		191	222	111	524		221		103	324		100			100	1257	

Table B20. cont.

	small					medium					large					unclassified					All	Sampling
	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Total	Intensity
1996 mt	23	34	80	43	181	96	207	531	269	1103	208	331	416	280	1234	110	152	339	169	769	3287	122
N					0	1		4	4	9		2	4	5	11	1	1	3	2	7	27	
# fish					0	101		435	541	1077		202	451	759	1412	127	72	326	220	745	3234	
1997 mt	31	58	124	83	295	76	113	370	193	752	146	146	438	335	1066	34	28	26	26	113	2225	32
N	4	2	4	2	12	3	7	6	13	29	5	7	7	9	28				1	1	70	
# fish	458	206	430	261	1355	276	694	564	1200	2734	541	720	678	896	2835				58	58	6982	
1998 mt	31	54	128	105	318	55	77	218	152	502	159	311	571	407	1449	28	23	34	14	100	2370	74
N	1	2	1	1	5	3		3	2	8	7	2	8	1	18			1		1	32	
# fish	53	220	120	59	452	327		402	305	1034	684	213	1311	110	2318			118		118	3922	
1999 mt	50	76	103	87	317	85	110	236	149	580	303	468	633	257	1661	11	14	25	16	66	2624	119
N			1		1	1	1	3	4	9	1	6	2	3	12					0	22	
# fish			119		119	111	102	315	313	841	166	665	202	327	1360					0	2320	
2000 mt	55	70	81	81	286	118	202	289	201	811	293	497	596	446	1833	14	15	20	12	60	2990	120
N	4			1	5	5	1	5	4	15	1	1		3	5					0	25	
# fish	428			123	551	527	106	573	450	1656	103	126		336	565					0	2772	
2001 mt	59	122	167	177	525	131	155	219	310	815	413	497	697	434	2041	10	22	57	12	101	3482	97
N	2	3	2	2	9	2	1	2	2	7	3	4	7	6	20					0	36	
# fish	231	329	213	224	997	221	100	235	215	771	328	456	797	660	2241					0	4009	
2002 mt	124.544	58	51	31	264	330	186	234	163	912	454	378	640	576	2047	7	14	15	6	43	3266	58
N		2	1	11	14	6	4	4	7	21	7	4	7	3	21					0	56	
# fish		154	103	968	1225	626	391	417	629	2063	768	372	665	335	2140					0	5428	
2003 mt	35	20	42	32	129	153	92	158	134	537	918.472	996.55	1065.672	742.897	3724	6	5	26	9	46	4435	46
N	3	6	6	4	19	4	8	4	8	24	6	14	17	17	54					0	97	
# fish	249	424	306	208	1187	355	768	387	796	2306	576	1369	1620	1665	5230					0	8723	
2004 mt	17	17	44	38	116	113	87	180	122	503	869	632	721	420	2642	5	53	98	88	245	3505	42
N	2	3		7	12	5	5	2	6	18	20	14	5	15	54					0	84	
# fish	83	162		445	690	383	456	211	579	1629	2062	1474	524	1213	5273					0	7592	
2005 mt	22	24	33	24	102	79	84	167	120	450	446	352	418	246	1463	270	148	137	104	659	2673	30
N	7	7	8	6	28	3	5	6	5	19	9	10	8	11	38	1	1	1		3	88	
# fish	349	360	400	313	1422	161	494	554	493	1702	825	924	738	973	3460	28	111	61		200	6784	
2006 mt	27	10	14	17	67	69	48	78	76	271	336	163	299	226	1025	193	47	49	66	355	1718	18
N	6	9	5	9	29	5	3	6	6	20	12	13	9	10	44					0	93	
# fish	372	398	254	547	1571	434	263	534	601	1832	958	1013	776	972	3719					0	7122	

Table B20. cont.

	small					medium					large					unclassified					All	Sampling
	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Q1	Q2	Q3	Q4	sum	Total	Intensity
2007 mt	11	16	31	41	99	39	53	75	76	244	207	220	338	198	963	75	59	59	28	222	1528	15
N	12	6	7	10	35	5	5	7	7	24	9	8	10	11	38	1	1			2	99	
# fish	478	264	325	388	1455	396	386	428	618	1828	753	716	667	922	3058	100	101			201	6542	
2008 mt	22	20	50	40	132	48	44	110	114	316	176	125	308	203	813	28	18	18	9	73	1335	14
N	5	5	6	7	23	7	5	6	6	24	11	17	8	10	46					0	93	
# fish	283	255	328	385	1251	474	356	528	616	1974	597	1106	790	677	3170					0	6395	
2009 mt	36	32	42	74	184	75	76	120	144	415	270	203	334	220	1028	29	15	11	15	70	1697	20
N	5	5	8	6	24	5	4	7	5	21	10	8	10	13	41					0	86	
# fish	282	279	599	519	1679	385	209	285	506	1385	773	558	1113	1104	3548					0	6612	
2010 mt	59	28	30	31	147	131	83	109	124	447	360	270	267	242	1139	38	9	13	15	75	1807	15
N	11	6	8	9	34	7	8	11	10	36	10	12	17	11	50					0	120	
# fish	500	483	580	428	1991	645	704	866	681	2896	953	1071	1203	898	4125					0	9012	
2011 mt	32	30	45	52	160	147	128	189	190	654	589	436	503	423	1952	56	23	14	18	111	2877	22
N	14	7	10	8	39	7	8	12	7	34	12	16	19	13	60						133	
# fish	542	390	611	418	1961	677	710	1069	700	3156	974	987	1199	1048	4208						9325	

Table B21. Proportion of red/white hake market category by mesh size (large >= 5.5 in, small < 5.5 in).

	LARGE	SMALL	UNK
1986	0.317	0.122	0.561
1987	0.388	0.027	0.584
1988	0.159	0.090	0.751
1989	0.151	0.031	0.817
1990	0.086	0.022	0.892
1991	0.155	0.043	0.802
1992	0.206	0.056	0.738
1993	0.288	0.087	0.625
1994	0.111	0.046	0.843
1995	0.178	0.517	0.304
1996	0.111	0.295	0.594
1997	0.033	0.645	0.322
1998	0.012	0.623	0.366
1999	0.047	0.350	0.603
2000	0.233	0.465	0.302
2001	0.360	0.131	0.508
2002	0.014	0.013	0.973
2003	0.000	0.044	0.956
2004	0.341	0.022	0.637
2005	0.286	0.269	0.445
2006	0.569	0.053	0.378
2007	0.097	0.097	0.806
2008	0.017	0.391	0.593
2009	0.050	0.396	0.554
2010	0.036	0.326	0.638
2011	0.226	0.644	0.131
AVG	0.172	0.223	0.605

Table B22. Number of ages from NEFSC survey and NEFOP data from 1982-2012 used to age the commercial length composition.
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Year	Spring	Obs Half 1	Autumn	Obs Half 2	Grand Total
1982	362		283		760
1983	309		483		792
1984	224		450		716
1985	411		652		1063
1986	686		669		1355
1987	191		443		634
1988	276		476		752
1989	259	36	472	90	731
1990	436	46	717	67	1153
1991	499	197	861	411	1360
1992	360	99	789	244	1149
1993	380	44	686	140	1066
1994	282	26	582	113	864
1995	256	123	542	208	798
1996	199	122	279	269	478
1997	113	136	277	224	390
1998	184	40	359		543
1999	210	57	374	209	584
2000	289	168	424	104	866
2001	323		328		651
2002	249		256		505
2003	235				235
2004	95		186		281
2005	237		207		444
2006	160		253		413
2007	184		488		672
2008	247		469		716
2009	775		822		1597
2010	755		952		1707
2011	697		737		1434
2012	616				616

Table B23. Total commercial landings-at-age (in 000s of fish) of white hake. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1985	0.000	0.000	11.985	630.707	1970.224	733.597	155.049	40.955	21.445	19.059	32.482		3615.505	3615.505	51.541
1986	0.000	0.000	13.846	303.056	437.697	324.864	227.450	137.260	78.481	103.849	147.913		1774.417	1774.417	251.762
1987	0.000	0.000	59.514	961.112	781.298	333.479	182.991	91.993	84.136	45.531	65.667		2605.721	2605.721	111.198
1988	0.000	1.308	80.063	1079.134	1264.266	515.114	105.235	15.779	10.526	4.910	28.747		3105.082	3105.082	33.657
1989	0.000	0.000	6.988	657.147	1006.232	593.181	259.583	39.802	22.835	9.927	12.614		2608.309	2608.309	22.542
1990	0.000	0.089	133.434	1226.335	1230.294	385.303	84.582	32.369	13.700	8.114	17.028		3131.248	3131.248	25.141
1991	0.000	0.000	62.055	1151.316	1307.508	750.988	174.022	40.128	14.677	8.691	26.002		3535.388	3535.388	34.693
1992	0.000	0.000	33.645	2022.094	1904.283	802.618	360.416	177.423	40.679	10.546	16.994		5368.698	5368.698	27.539
1993	0.000	0.000	4.165	1471.175	2271.586	866.068	299.926	99.479	12.406	7.356	13.378		5045.539	5045.539	20.734
1994	0.000	0.887	67.590	777.515	1100.425	600.293	257.221	86.974	28.903	8.904	13.158		2941.869	2941.869	22.062
1995	0.000	0.000	271.449	1594.567	765.135	330.931	168.725	29.044	24.406	18.229	5.807		3208.292	3208.292	24.036
1996	0.000	0.000	27.800	334.470	500.437	418.158	255.623	66.991	14.311	7.573	6.949		1632.313	1632.313	14.523
1997	0.000	0.006	0.603	78.054	222.095	314.080	191.734	78.599	21.458	8.417	5.073		920.118	920.118	13.490
1998	0.000	0.000	5.598	75.060	178.858	189.711	167.538	97.550	38.005	15.658	6.466		774.443	774.443	22.123
1999	0.000	0.000	0.289	139.347	188.529	231.910	160.579	97.964	73.340	23.068	12.418		927.443	927.443	35.486
2000	0.000	0.000	0.878	28.333	228.809	250.977	162.903	85.773	91.112	70.400	16.147		935.330	935.330	86.547
2001	0.000	0.000	7.585	250.079	315.558	222.062	204.681	113.895	68.843	39.219	14.379		1236.301	1236.301	53.598
2002	0.000	0.000	42.692	221.180	410.986	228.243	185.552	92.931	41.117	10.522	3.832		1237.054	1237.054	14.354
2003	**0.000**	**0.000**	**0.325**	**30.542**	**145.131**	**232.402**	**268.268**	**210.928**	**115.347**	**58.815**	**17.026**		**1078.784**	**1078.784**	**75.841**
2004	0.000	0.000	1.354	32.100	87.810	195.359	169.930	141.138	84.541	45.334	27.378		784.943	784.943	72.712
2005	0.000	0.000	1.248	18.828	100.608	134.111	103.267	134.709	80.491	26.036	56.430		655.727	655.727	82.465
2006	0.000	0.000	1.651	24.327	51.685	72.473	117.648	57.376	51.869	16.103	27.037		420.167	420.167	43.140
2007	0.000	0.000	3.252	45.931	60.555	55.322	74.157	49.135	31.335	13.865	20.694		354.247	354.247	34.560
2008	0.000	0.000	2.145	52.080	115.263	63.722	85.066	39.859	24.534	10.259	7.665		400.594	400.594	17.925
2009	0.000	0.063	14.525	57.691	123.626	122.091	109.050	62.576	40.220	7.245	24.496		561.583	561.583	31.741
2010	0.000	0.018	2.603	55.548	123.403	122.692	83.355	35.213	27.163	14.516	38.637		503.149	503.149	53.154
2011	0.000	0.037	1.621	57.315	155.066	146.338	147.186	84.948	54.713	27.812	41.755		716.790	716.790	69.567

Table B24. Total commercial landings-at-age (in mt) of white hake. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1985	0.000	0.000	7.920	649.196	3743.976	2280.435	678.828	227.944	143.692	157.520	414.960		8304.470	8304.470	572.480
1986	0.000	0.000	8.633	299.996	693.079	964.599	1034.470	798.792	553.717	866.681	2044.191		7264.158	7264.158	2910.872
1987	0.000	0.000	31.832	956.418	1450.867	1028.682	868.012	477.124	545.728	350.326	885.379		6594.367	6594.367	1235.705
1988	0.000	0.229	45.318	1160.849	2236.962	1347.521	409.153	76.339	68.864	37.643	469.701		5852.578	5852.578	507.344
1989	0.000	0.000	4.563	677.234	1778.709	1640.801	989.572	214.376	136.362	78.817	128.653		5649.087	5649.087	207.470
1990	0.000	0.026	75.192	1421.244	2165.320	1127.046	352.163	162.412	92.958	68.275	226.206		5690.843	5690.843	294.481
1991	0.000	0.000	35.287	1268.609	2060.793	1752.400	577.150	166.092	89.219	78.777	297.834		6326.160	6326.160	376.611
1992	0.000	0.000	20.850	1966.298	2821.781	2005.649	1431.817	871.946	237.206	83.103	208.658		9647.308	9647.308	291.761
1993	0.000	0.000	2.102	1492.141	3636.683	2253.250	1099.945	400.805	75.191	53.653	171.983		9185.752	9185.752	225.637
1994	0.000	0.168	24.092	725.870	1662.547	1567.544	973.175	423.867	197.180	65.724	141.713		5781.880	5781.880	207.437
1995	0.000	0.000	158.943	1711.129	1251.512	775.696	503.376	121.964	136.880	96.291	70.993		4826.783	4826.783	167.284
1996	0.000	0.000	16.052	364.174	858.959	1077.509	867.119	275.304	94.596	43.465	70.831		3668.008	3668.008	114.295
1997	0.000	0.002	0.338	77.450	384.894	805.624	674.691	352.793	127.560	57.907	47.902		2529.162	2529.162	105.809
1998	0.000	0.000	2.912	88.818	364.530	574.742	704.401	465.956	234.488	107.919	53.942		2597.709	2597.709	161.862
1999	0.000	0.000	0.172	98.990	304.172	574.899	606.003	476.559	463.662	167.727	109.584		2801.768	2801.768	277.311
2000	0.000	0.000	0.503	29.105	404.468	640.007	546.463	403.142	572.154	480.207	146.269		3222.318	3222.318	626.476
2001	0.000	0.000	3.791	355.662	565.702	573.872	781.287	579.882	421.089	274.174	129.303		3684.760	3684.760	403.477
2002	0.000	0.000	50.462	335.763	927.586	664.689	713.896	414.763	220.306	68.310	29.967		3425.743	3425.743	98.277
2003	**0.000**	**0.000**	**0.311**	**41.643**	**315.988**	**747.426**	**1141.925**	**1102.744**	**677.288**	**390.006**	**146.319**		**4563.649**	**4563.649**	**536.324**
2004	0.013	13.309	139.592	194.463	159.612	475.291	632.555	831.028	574.129	355.713	232.835		3608.541	3608.528	588.549
2005	0.000	0.000	1.031	26.663	198.086	377.565	417.825	624.841	470.623	186.584	452.501		2755.718	2755.718	639.085
2006	0.000	0.000	1.256	33.553	92.758	219.805	473.056	265.231	277.587	132.783	296.427		1792.457	1792.457	429.210
2007	0.000	0.000	3.055	73.113	163.533	242.432	347.499	241.495	171.357	97.023	246.308		1585.816	1585.816	343.332
2008	0.000	0.000	1.737	78.838	262.157	216.079	339.552	192.115	129.937	64.668	94.530		1379.612	1379.612	159.198
2009	0.000	0.023	9.915	73.606	230.131	337.669	439.637	295.412	208.701	49.641	145.865		1790.601	1790.601	195.505
2010	0.000	0.012	2.734	111.384	345.280	351.781	339.757	177.209	160.184	93.660	341.852		1923.854	1923.854	435.513
2011	0.000	0.013	1.090	105.823	396.788	485.390	593.156	424.179	359.902	214.712	403.497		2984.549	2984.549	618.208

Table B25. Total commercial landed mean weights-at-age of white hake. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1985			0.661	1.029	1.900	3.109	4.378	5.566	6.700	8.265	12.775		2.297	2.297	11.107
1986			0.623	0.990	1.583	2.969	4.548	5.820	7.055	8.346	13.820		4.094	4.094	11.562
1987			0.535	0.995	1.857	3.085	4.743	5.187	6.486	7.694	13.483		2.531	2.531	11.113
1988		0.175	0.566	1.076	1.769	2.616	3.888	4.838	6.543	7.667	16.339		1.885	1.885	15.074
1989			0.653	1.031	1.768	2.766	3.812	5.386	5.972	7.939	10.199		2.166	2.166	9.204
1990		0.291	0.564	1.159	1.760	2.925	4.164	5.017	6.785	8.415	13.284		1.817	1.817	11.713
1991			0.569	1.102	1.576	2.333	3.317	4.139	6.079	9.064	11.454		1.789	1.789	10.855
1992			0.620	0.972	1.482	2.499	3.973	4.914	5.831	7.880	12.279		1.797	1.797	10.594
1993			0.505	1.014	1.601	2.602	3.667	4.029	6.061	7.293	12.856		1.821	1.821	10.882
1994		0.190	0.356	0.934	1.511	2.611	3.783	4.874	6.822	7.382	10.770		1.965	1.965	9.402
1995			0.586	1.073	1.636	2.344	2.983	4.199	5.609	5.282	12.226		1.504	1.504	6.960
1996			0.577	1.089	1.716	2.577	3.392	4.110	6.610	5.739	10.193		2.247	2.247	7.870
1997		0.259	0.561	0.992	1.733	2.565	3.519	4.489	5.945	6.880	9.443		2.749	2.749	7.844
1998			0.520	1.183	2.038	3.030	4.204	4.777	6.170	6.892	8.343		3.354	3.354	7.316
1999			0.596	0.710	1.613	2.479	3.774	4.865	6.322	7.271	8.825		3.021	3.021	7.815
2000			0.573	1.027	1.768	2.550	3.355	4.700	6.280	6.821	9.059		3.445	3.445	7.239
2001			0.500	1.422	1.793	2.584	3.817	5.091	6.117	6.991	8.992		2.980	2.980	7.528
2002			1.182	1.518	2.257	2.912	3.847	4.463	5.358	6.492	7.820		2.769	2.769	6.847
2003			**0.957**	**1.363**	**2.177**	**3.216**	**4.257**	**5.228**	**5.872**	**6.631**	**8.594**		**4.230**	**4.230**	**7.072**
2004	0.763		0.704	1.346	2.011	3.407	4.279	5.897	6.792	7.847	8.504		4.597	4.597	8.094
2005			0.826	1.416	1.969	2.815	4.046	4.638	5.847	7.167	8.019		4.203	4.203	7.750
2006			0.761	1.379	1.795	3.033	4.021	4.623	5.352	8.246	10.964		4.266	4.266	9.949
2007			0.939	1.592	2.701	4.382	4.686	4.915	5.469	6.998	11.902		4.477	4.477	9.934
2008			0.810	1.514	2.274	3.391	3.992	4.820	5.296	6.303	12.332		3.444	3.444	8.881
2009		0.367	0.683	1.276	1.862	2.766	4.032	4.721	5.189	6.852	5.955		3.188	3.188	6.159
2010		0.651	1.050	2.005	2.798	2.867	4.076	5.033	5.897	6.452	8.848		3.824	3.824	8.193
2011		0.363	0.672	1.846	2.559	3.317	4.030	4.993	6.578	7.720	9.663		4.164	4.164	8.887

Table B26. Percentage by age of landings-at-age (000s of fish) that were filled out to account for missing ages-at-length. The total is the percentage of the entire landings-at-age.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1985	0.00	0.00	0.00	0.00	0.06	1.82	28.79	77.32	80.19	97.97	94.08		4.35	4.35	95.51
1986	0.00	0.00	0.00	0.00	0.79	7.87	21.53	42.47	91.67	73.92	97.08		24.15	24.15	87.52
1987	0.00	0.00	0.00	1.02	9.11	34.04	39.95	46.13	49.55	54.87	93.87		16.82	16.82	77.90
1988	0.00	0.00	0.00	0.88	1.41	9.63	48.42	92.33	95.53	100.00	100.00		6.00	6.00	100.00
1989	0.00	0.00	0.00	0.95	6.19	5.46	14.59	59.87	56.93	100.00	71.65		7.46	7.46	84.13
1990	0.00	0.00	0.00	0.00	0.01	0.48	12.60	27.65	75.74	83.09	88.72		1.72	1.72	86.91
1991	0.00	0.00	0.00	0.00	0.00	0.05	1.46	5.06	43.26	92.10	90.10		1.21	1.21	90.60
1992	0.00	0.00	0.00	0.00	0.00	0.27	2.61	4.30	12.73	63.00	95.97		0.88	0.88	83.34
1993	0.00	0.00	0.00	0.00	0.08	1.64	8.65	29.45	100.00	77.12	100.00		2.04	2.04	91.88
1994	0.00	0.00	0.00	0.04	1.09	6.61	15.28	30.99	80.36	100.00	100.00		5.56	5.56	100.00
1995	0.00	0.00	0.00	0.00	0.00	0.90	6.82	30.81	19.24	1.25	76.47		1.02	1.02	19.42
1996	0.00	0.00	0.00	0.00	0.07	1.25	7.26	16.93	33.03	59.99	76.07		3.06	3.06	67.69
1997	0.00	100.00	11.20	0.05	0.53	3.46	11.68	20.48	42.36	56.87	72.55		7.41	7.41	62.76
1998	0.00	0.00	0.00	0.69	12.65	39.30	62.44	55.11	85.98	100.00	100.00		40.14	40.14	100.00
1999	0.00	0.00	0.00	1.46	4.77	1.07	6.70	13.68	18.30	70.27	80.88		8.34	8.34	73.98
2000	0.00	0.00	0.00	0.00	0.80	7.11	25.13	29.33	18.67	12.76	78.79		13.31	13.31	25.08
2001	0.00	0.00	0.00	0.00	0.83	12.13	33.55	56.67	79.14	86.83	97.90		21.46	21.46	89.80
2002	0.00	0.00	1.05	3.42	2.66	10.90	44.10	68.63	83.65	100.00	100.00		19.26	19.26	100.00
2003	**0.00**	**0.00**	**5.09**	**0.70**	**0.02**	**3.55**	**12.22**	**17.47**	**48.32**	**35.30**	**41.95**		**15.00**	**15.00**	**36.79**
2004	0.00	0.00	0.00	13.64	42.05	32.81	77.59	100.00	91.79	83.91	100.00		66.43	66.43	89.97
2005	0.00	0.00	4.85	30.41	9.79	16.31	51.79	28.81	33.24	68.17	44.95		30.45	30.45	52.28
2006	0.00	0.00	0.00	7.12	23.86	44.36	50.94	74.61	53.99	100.00	92.12		51.88	51.88	95.06
2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.64		1.15	1.15	11.76
2008	0.00	0.00	0.00	0.00	0.73	13.74	8.15	2.36	0.71	0.68	18.06		4.77	4.77	8.11
2009	0.00	0.00	0.00	0.00	3.72	11.11	30.45	56.44	58.94	100.00	14.21		21.57	21.57	33.79
2010	0.00	0.00	0.00	0.00	0.00	0.82	6.17	31.22	54.48	54.61	48.02		11.61	11.61	49.82
2011	0.00	0.00	0.00	0.00	0.20	0.00	11.46	35.84	70.61	81.74	69.12		19.23	19.23	74.17

Table B27. Percentage by age of landings-at-age (mt) that were filled out to account for missing ages-at-length. The total is the percentage of the entire landings-at-age.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1985	0.00	0.00	0.00	0.00	0.13	2.44	32.29	78.12	78.31	97.98	95.36		13.49	13.49	96.09
1986	0.00	0.00	0.00	0.00	1.57	9.09	24.10	45.31	90.95	74.63	97.54		53.06	53.06	90.72
1987	0.00	0.00	0.00	2.28	11.50	29.39	35.50	48.54	52.11	53.15	94.45		35.45	35.45	82.74
1988	0.00	0.00	0.00	0.75	1.79	14.07	49.79	93.03	96.06	100.00	100.00		18.56	18.56	100.00
1989	0.00	0.00	0.00	1.12	5.22	5.10	15.81	56.79	61.05	100.00	79.94		12.87	12.87	87.56
1990	0.00	0.00	0.00	0.00	0.04	0.83	16.80	32.15	72.30	80.75	89.67		7.85	7.85	87.60
1991	0.00	0.00	0.00	0.00	0.00	0.10	2.63	8.09	54.42	92.39	92.20		6.74	6.74	92.24
1992	0.00	0.00	0.00	0.00	0.00	0.46	3.26	4.70	15.44	68.39	96.18		4.05	4.05	88.27
1993	0.00	0.00	0.00	0.00	0.17	2.53	10.52	35.28	100.00	78.23	100.00		6.64	6.64	94.82
1994	0.00	0.00	0.00	0.08	1.68	7.45	17.66	33.49	79.27	100.00	100.00		14.23	14.23	100.00
1995	0.00	0.00	0.00	0.00	0.00	1.60	9.64	32.62	23.40	1.63	76.93		3.91	3.91	33.59
1996	0.00	0.00	0.00	0.00	0.14	1.92	9.50	19.82	29.38	77.63	80.73		7.56	7.56	79.55
1997	0.00	100.00	5.17	0.01	1.30	5.29	15.89	25.07	45.14	58.82	74.46		14.65	14.65	65.90
1998	0.00	0.00	0.00	1.28	18.29	45.55	63.28	58.81	84.56	100.00	100.00		54.26	54.26	100.00
1999	0.00	0.00	0.00	2.11	4.07	1.90	11.15	19.38	24.31	70.14	81.96		18.04	18.04	74.81
2000	0.00	0.00	0.00	0.00	1.81	11.00	33.08	32.52	19.86	14.13	78.47		21.28	21.28	29.15
2001	0.00	0.00	0.00	0.00	1.74	19.34	41.49	59.01	79.52	86.98	97.96		40.36	40.36	90.50
2002	0.00	0.00	0.75	2.06	2.24	15.85	51.92	76.79	90.20	100.00	100.00		32.68	32.68	100.00
2003	**0.00**	**0.00**	**2.96**	**0.29**	**0.01**	**4.99**	**13.46**	**18.18**	**48.51**	**33.64**	**42.02**		**20.00**	**20.00**	**35.93**
2004	0.00	0.00	0.00	19.11	45.79	34.56	83.53	100.00	90.34	82.63	100.00		77.72	77.72	89.50
2005	0.00	0.00	8.62	32.43	10.01	21.77	58.40	30.97	36.04	75.51	59.65		40.96	40.96	64.28
2006	0.00	0.00	0.00	7.51	28.91	53.19	56.37	82.64	64.84	100.00	96.44		68.66	68.66	97.54
2007	0.00	0.00	0.00	0.81	16.22	24.30	7.21	0.96	0.59	0.38	23.33		10.86	10.86	16.85
2008	0.00	0.00	0.00	0.00	1.01	12.18	6.56	1.66	0.52	0.32	21.42		5.48	5.48	12.85
2009	0.00	0.00	0.00	0.00	6.06	14.20	34.91	61.89	66.95	100.00	24.90		34.84	34.84	43.97
2010	0.00	0.00	0.00	0.00	0.00	1.47	8.80	38.76	62.66	66.73	75.67		27.31	27.31	73.75
2011	0.00	0.00	0.00	0.00	0.43	0.00	15.12	42.27	72.43	84.93	82.43		35.06	35.06	83.29

Table B28. Number of lengths sampled in the NEFOP data for white hake in small and large mesh otter trawls.

	OT Large						OT Small					
	Half 1		Half 2		Total		Half 1		Half 2		Total	
Year	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc
1989		221	12	715	12	936	1	479	92	698	93	1177
1990	63	8		9	63	17	1	8	138	303	139	311
1991	1		413	43	414	43				2	0	2
1992	206		59	86	265	86	22				22	0
1993	542	51	658	14	1200	65	2			30	2	30
1994	190	26	99	2	289	28			14	2	14	2
1995	852	161	403	166	1255	327			294	106	294	106
1996	144	31	25		169	31		145	306	335	306	480
1997	67	39	84	64	151	103		29			0	29
1998	23	11	12	2	35	13					0	0
1999	23		113	42	136	42					0	0
2000	291	12	454		745	12		107	8	12	8	119
2001	38		391		429	0	7	42			7	42
2002	125		806	128	931	128			22	14	22	14
2003	2071	24	1381	196	3452	220	202	1	827	2	1029	3
2004	1031	190	1694	604	2725	794	276	93	128	185	404	278
2005	3009	489	3010	730	6019	1219	198	91	660	217	858	308
2006	1801	506	1532	415	3333	921	224	19	25		249	19
2007	611	209	1394	219	2005	428	68	39	16	3	84	42
2008	791	126	1739	487	2530	613	2	6	6	36	8	42
2009	1353	100	1227	217	2580	317		1	76	12	76	13
2010	1954	114	1368	85	3322	199	14	2	14	3	28	5
2011	1388	27	921	10	2309	37	75		110	1	185	1
Total 1989-2011	17408	2359	17964	4257	35372	6616	1092	1066	1961	2736	3828	3027

Table B29. Number of lengths sampled in the NEFOP data for white hake in sink gill net and longline fisheries.

	SGN						Longline					
	Half 1		Half 2		Total		Half 1		Half 2		Total	
Year	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc
1989			484	2	484	2						
1990	196		1061	32	1257	32						
1991	2448	135	9973	30	12421	165						
1992	1620		8451	4	10071	4	1				1	
1993	1239	1	3968	13	5207	14						
1994	44		1766	4	1810	4						
1995	167	1	2599	30	2766	31						
1996	70	12	826	3	896	15						
1997	85		427	4	512	4						
1998	36		411	1	447	1						
1999	79		218	20	297	20						
2000	47	9	143		190	9						
2001	16	4	8	2	24	6						
2002	6		74	2	80	2						
2003	182	8	748	52	930	60						
2004	185	6	3108	69	3293	75			23	9	23	9
2005	42	3	4455	35	4497	38	3		165	34	168	34
2006	160	2	683	4	843	6		1	14	10	14	11
2007	339	7	501	5	840	12			8		8	
2008	236	3	509	6	745	9		5	127	125	127	130
2009	147	2	553	3	700	5		4	13	13	13	17
2010	828	3	676	1	1504	4	158	1	37		195	1
2011	329		1274	11	1603	11			4	6	4	6
Total 1989-2011	8501	196	42916	333	51417	529	162	11	391	197	553	208

Table B30. Pooling scheme for otter trawl discards by mesh size and half year.

<table>
<tr><th></th><th colspan="2">Large</th><th colspan="2">Small</th></tr>
<tr><th></th><th>1</th><th>2</th><th>1</th><th>2</th></tr>
<tr><td>1989</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1990</td><td rowspan="4"></td><td rowspan="4"></td><td colspan="2"></td></tr>
<tr><td>1991</td><td rowspan="6"></td><td rowspan="6"></td></tr>
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<tr><td>1995</td></tr>
<tr><td>1996</td><td rowspan="2"></td><td rowspan="4"></td></tr>
<tr><td>1997</td><td rowspan="5"></td><td rowspan="8"></td></tr>
<tr><td>1998</td><td rowspan="6"></td></tr>
<tr><td>1999</td></tr>
<tr><td>2000</td><td rowspan="3"></td></tr>
<tr><td>2001</td></tr>
<tr><td>2002</td><td></td></tr>
<tr><td>2003</td><td></td><td rowspan="2"></td></tr>
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<tr><td>2005</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2006</td><td></td><td></td><td rowspan="6"></td><td rowspan="6"></td></tr>
<tr><td>2007</td><td></td><td></td></tr>
<tr><td>2008</td><td></td><td></td></tr>
<tr><td>2009</td><td></td><td></td></tr>
<tr><td>2010</td><td></td><td></td></tr>
<tr><td>2011</td><td>+2012</td><td>+2012</td></tr>
</table>

Table B31. Number of lengths sampled in the NEFOP data for white hake in shrimp trawl and scallop dredge.

	Shrimp						Scallop					
	Half 1		Half 2		Total		Half 1		Half 2		Total	
Year	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc	Kept	Disc
1989		200				200						
1990		37				37						
1991	52				52							
1992	37	17		58	37	75						
1993		282				282		1	1		1	1
1994		517		256		773		1		3		4
1995		958				958		51	1	73	1	124
1996		325		15		340				1		1
1997		25				25				1		1
1998							1	5		63	1	68
1999										35		35
2000								2				2
2001												
2002												
2003		1				1		2				2
2004			111		111			7		223		230
2005	157	28			157	28			2	67	2	67
2006		131				131		1	1	5	1	6
2007		43				43		13		29		42
2008		31		25		56		8		56		64
2009		13		1		14	1	3		1	1	4
2010								1		15		16
2011										9		9
Total 1989-2011	246	2608	111	355	357	2963	2	95	5	581	7	676

Table B32. Total commercial discards-at-age (in 000s of fish) of white hake. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	11.875	701.123	1705.570	655.103	36.284	2.113	0.000	0.000	0.000	0.000	0.000		3112.068	3100.192	0.000
1990	25.958	700.325	3470.954	1260.777	89.526	0.000	0.000	0.000	0.000	0.000	0.000		5547.540	5521.581	0.000
1991	19.508	412.309	343.891	172.150	13.716	0.000	0.000	0.000	0.000	0.000	0.000		961.574	942.066	0.000
1992	59.662	198.594	309.239	746.127	222.685	0.000	0.000	0.000	0.000	0.000	0.000		1536.306	1476.645	0.000
1993	9.849	1417.738	2479.071	655.043	22.670	0.000	0.000	0.000	0.000	0.000	0.000		4584.370	4574.522	0.000
1994	0.889	163.880	281.913	295.930	39.619	5.771	0.609	0.012	0.000	0.000	0.000		788.623	787.734	0.000
1995	0.000	105.129	196.167	259.776	20.981	2.831	1.980	0.000	0.000	0.000	0.000		586.864	586.864	0.000
1996	0.000	43.939	109.216	224.869	21.850	1.309	1.633	0.930	0.089	0.000	0.000		403.835	403.835	0.000
1997	0.000	10.689	149.855	43.065	12.173	6.887	1.453	0.889	0.000	0.000	0.000		225.011	225.011	0.000
1998	5.691	60.696	208.034	67.211	21.588	2.923	0.062	0.000	0.000	0.000	0.000		366.205	360.514	0.000
1999	137.352	1517.289	826.295	220.970	90.048	56.567	11.006	0.000	0.000	0.000	0.000		2859.527	2722.175	0.000
2000	5.532	30.301	112.303	104.140	34.667	19.673	6.091	0.033	0.442	0.000	0.000		313.183	307.651	0.000
2001	0.312	27.429	153.337	133.392	57.965	24.274	11.414	2.373	0.178	0.000	0.000		410.675	410.363	0.000
2002	18.014	18.460	43.552	31.557	25.610	4.906	0.781	0.740	0.064	0.000	0.000		143.685	125.671	0.000
2003	**116.945**	**420.844**	**241.151**	**87.974**	**31.144**	**13.520**	**2.186**	**0.307**	**0.034**	**0.000**	**0.000**		**914.104**	**797.159**	**0.000**
2004	18.371	91.000	73.112	59.531	11.407	1.603	1.295	0.060	0.030	0.000	0.000		256.409	238.038	0.000
2005	289.926	62.779	30.945	30.313	6.962	0.413	0.148	0.062	0.033	0.000	0.000		421.580	131.654	0.000
2006	9.547	78.077	37.466	20.750	4.073	0.406	0.010	0.001	0.066	0.000	0.000		150.395	140.848	0.000
2007	8.083	19.977	22.578	18.417	3.076	1.002	0.060	0.046	0.007	0.000	0.000		73.246	65.163	0.000
2008	71.205	72.768	80.549	111.830	24.451	0.984	0.000	0.000	0.000	0.000	0.000		361.787	290.583	0.000
2009	33.184	44.015	42.534	37.104	16.898	2.759	0.716	0.062	0.018	0.009	0.000		177.299	144.115	0.009
2010	6.219	18.388	31.485	35.780	17.660	3.317	0.529	0.070	0.000	0.000	0.000		113.447	107.229	0.000
2011	3.225	12.739	18.334	17.913	4.732	0.726	0.199	0.000	0.000	0.000	0.000		57.869	54.644	0.000

Table B33. Total commercial discards-at-age (in mt) of white hake. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	2.158	99.401	528.085	428.052	40.017	4.876	0.000	0.000	0.000	0.000	0.000		1102.589	1100.431	0.000
1990	1.327	122.669	1095.647	534.377	54.971	0.000	0.000	0.000	0.000	0.000	0.000		1808.991	1807.664	0.000
1991	1.037	59.561	134.247	106.828	10.768	0.000	0.000	0.000	0.000	0.000	0.000		312.441	311.404	0.000
1992	3.308	21.184	112.952	384.409	123.756	0.000	0.000	0.000	0.000	0.000	0.000		645.610	642.302	0.000
1993	0.420	175.750	676.951	394.194	23.237	0.000	0.000	0.000	0.000	0.000	0.000		1270.551	1270.131	0.000
1994	0.040	21.148	81.033	140.101	40.298	12.899	2.019	0.024	0.000	0.000	0.000		297.563	297.523	0.000
1995	0.000	15.951	77.667	139.048	22.753	5.599	5.284	0.000	0.000	0.000	0.000		266.303	266.303	0.000
1996	0.000	5.886	30.221	96.356	20.982	3.010	5.690	3.502	0.375	0.000	0.000		166.022	166.022	0.000
1997	0.000	1.583	41.082	20.078	19.153	14.398	4.418	3.681	0.000	0.000	0.000		104.392	104.392	0.000
1998	0.113	8.370	54.128	39.228	36.365	6.764	0.135	0.000	0.000	0.000	0.000		145.104	144.991	0.000
1999	4.892	163.008	267.435	150.906	165.215	135.546	34.271	0.000	0.000	0.000	0.000		921.273	916.381	0.000
2000	0.236	3.541	24.621	52.895	46.750	50.487	17.738	0.132	2.292	0.000	0.000		198.692	198.456	0.000
2001	0.045	6.494	33.646	85.266	77.114	59.732	33.412	9.487	0.905	0.000	0.000		306.100	306.055	0.000
2002	2.184	5.366	15.534	29.207	45.144	10.883	2.600	2.600	0.325	0.000	0.000		113.844	111.660	0.000
2003	**8.289**	**50.835**	**84.590**	**69.714**	**56.006**	**33.744**	**5.722**	**0.800**	**0.107**	**0.000**	**0.000**		**309.807**	**301.518**	**0.000**
2004	1.438	17.913	29.297	29.635	14.713	4.218	3.464	0.199	0.114	0.000	0.000		100.992	99.554	0.000
2005	20.829	10.770	15.609	18.840	7.438	0.936	0.349	0.236	0.124	0.000	0.000		75.132	54.303	0.000
2006	1.005	16.134	12.252	12.084	4.243	0.897	0.014	0.001	0.220	0.000	0.000		46.851	45.846	0.000
2007	0.660	4.226	8.537	12.326	3.685	1.718	0.205	0.204	0.031	0.000	0.000		31.591	30.931	0.000
2008	6.113	11.046	31.899	77.791	28.802	1.487	0.000	0.000	0.000	0.000	0.000		157.138	151.025	0.000
2009	2.474	7.413	18.328	24.364	15.755	3.927	2.136	0.212	0.067	0.033	0.000		74.710	72.236	0.033
2010	0.620	3.814	13.694	23.128	16.527	4.598	0.829	0.122	0.000	0.000	0.000		63.332	62.712	0.000
2011	0.231	2.183	8.055	13.391	5.502	0.951	0.305	0.000	0.000	0.000	0.000		30.618	30.387	0.000

Table B34. Total commercial discarded mean weights-at-age of white hake. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	0.182	0.142	0.310	0.653	1.103	2.308							0.354	0.355	
1990	0.051	0.175	0.316	0.424	0.614								0.326	0.327	
1991	0.053	0.144	0.390	0.621	0.785								0.325	0.331	
1992	0.055	0.107	0.365	0.515	0.556								0.420	0.435	
1993	0.043	0.124	0.273	0.602	1.025								0.277	0.278	
1994	0.045	0.129	0.287	0.473	1.017	2.235	3.316	2.040					0.377	0.378	
1995		0.152	0.396	0.535	1.084	1.978	2.668						0.454	0.454	
1996		0.134	0.277	0.428	0.960	2.299	3.484	3.767	4.227				0.411	0.411	
1997		0.148	0.274	0.466	1.573	2.091	3.041	4.142					0.464	0.464	
1998	0.020	0.138	0.260	0.584	1.684	2.314	2.190						0.396	0.402	
1999	0.036	0.107	0.324	0.683	1.835	2.396	3.114						0.322	0.337	
2000	0.043	0.117	0.219	0.508	1.349	2.566	2.912	3.950	5.191				0.634	0.645	
2001	0.145	0.237	0.219	0.639	1.330	2.461	2.927	3.999	5.094				0.745	0.746	
2002	0.121	0.291	0.357	0.926	1.763	2.218	3.329	3.514	5.094				0.792	0.889	
2003	**0.071**	**0.121**	**0.351**	**0.792**	**1.798**	**2.496**	**2.617**	**2.606**	**3.189**				**0.339**	**0.378**	
2004	0.078	0.197	0.401	0.498	1.290	2.632	2.674	3.351	3.793				0.394	0.418	
2005	0.072	0.172	0.504	0.622	1.068	2.265	2.363	3.835	3.806				0.178	0.412	
2006	0.105	0.207	0.327	0.582	1.042	2.211	1.442	1.244	3.332				0.312	0.326	
2007	0.082	0.212	0.378	0.669	1.198	1.715	3.400	4.402	4.402				0.431	0.475	
2008	0.086	0.152	0.396	0.696	1.178	1.511							0.434	0.520	
2009	0.075	0.168	0.431	0.657	0.932	1.423	2.984	3.431	3.731	3.731			0.421	0.501	3.731
2010	0.100	0.207	0.435	0.646	0.936	1.386	1.567	1.744					0.558	0.585	
2011	0.072	0.171	0.439	0.748	1.163	1.311	1.529						0.529	0.556	

Table B35. Percentage by age of discards-at-age (000s) that were filled out to account for missing ages-at-length. The total is the percentage of the entire discards-at-age.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	100.00	14.08	4.24	0.01	1.11	0.74	0.00	0.00	0.00	0.00	0.00		5.89	5.53	0.00
1990	5.08	1.58	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.27	0.25	0.00
1991	0.00	0.03	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.04	0.04	0.00
1992	0.00	2.72	2.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.85	0.88	0.00
1993	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
1994	0.00	0.46	0.00	0.00	1.11	17.08	7.80	100.00	0.00	0.00	0.00		0.28	0.29	0.00
1995	0.00	1.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.19	0.19	0.00
1996	0.00	0.00	0.00	0.00	0.00	7.91	37.88	46.50	100.00	0.00	0.00		0.31	0.31	0.00
1997	0.00	0.86	0.66	1.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.75	0.75	0.00
1998	33.33	10.50	1.58	0.41	20.44	59.10	100.00	0.00	0.00	0.00	0.00		4.92	4.48	0.00
1999	0.00	0.00	0.00	0.04	0.56	0.05	0.00	0.00	0.00	0.00	0.00		0.02	0.02	0.00
2000	35.63	0.55	0.00	0.00	0.07	0.76	3.56	100.00	1.89	0.00	0.00		0.82	0.20	0.00
2001	100.00	8.13	0.62	0.03	0.41	7.19	14.49	25.49	100.00	0.00	0.00		1.94	1.86	0.00
2002	4.10	2.60	2.80	4.65	9.74	5.46	29.59	24.78	100.00	0.00	0.00		4.97	5.10	0.00
2003	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		**0.00**	**0.00**	**0.00**
2004	15.82	5.81	2.46	0.53	17.58	23.02	21.39	100.00	100.00	0.00	0.00		5.09	4.26	0.00
2005	7.57	9.61	2.68	0.54	5.06	5.88	14.29	53.60	12.50	0.00	0.00		6.98	5.67	0.00
2006	12.66	12.07	2.80	7.96	15.84	13.21	100.00	100.00	0.00	0.00	0.00		9.34	9.11	0.00
2007	0.00	1.73	12.30	3.22	28.82	23.52	100.00	100.00	100.00	0.00	0.00		6.76	7.60	0.00
2008	0.05	0.07	0.36	0.35	0.03	0.00	0.00	0.00	0.00	0.00	0.00		0.21	0.25	0.00
2009	0.00	0.00	0.00	0.00	0.11	2.92	42.54	86.96	100.00	100.00	0.00		0.27	0.34	100.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00

Table B36. Percentage by age of discards-at-age (mt) that were filled out to account for missing ages-at-length. The total is the percentage of the entire discards-at-age.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	100.00	19.29	2.84	0.02	1.11	0.35	0.00	0.00	0.00	0.00	0.00		3.35	3.16	0.00
1990	3.17	0.44	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.04	0.04	0.00
1991	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01	0.01	0.00
1992	0.00	1.20	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.15	0.15	0.00
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
1994	0.00	0.06	0.00	0.02	2.23	15.60	4.80	100.00	0.00	0.00	0.00		1.03	1.03	0.00
1995	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.01	0.01	0.00
1996	0.00	0.00	0.00	0.00	0.00	13.96	44.91	51.37	100.00	0.00	0.00		3.10	3.10	0.00
1997	0.00	1.50	0.62	0.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.42	0.42	0.00
1998	13.30	3.47	0.38	1.55	26.57	55.93	100.00	0.00	0.00	0.00	0.00		10.13	10.13	0.00
1999	0.00	0.00	0.00	0.07	0.37	0.03	0.00	0.00	0.00	0.00	0.00		0.08	0.08	0.00
2000	27.38	0.18	0.00	0.00	0.21	1.17	4.82	100.00	1.44	0.00	0.00		0.90	0.87	0.00
2001	100.00	5.20	1.05	0.02	1.12	10.64	18.89	30.60	100.00	0.00	0.00		5.91	5.89	0.00
2002	1.05	1.55	2.56	4.56	5.84	6.60	38.63	35.58	100.00	0.00	0.00		6.54	6.65	0.00
2003	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**		**0.00**	**0.00**	**0.00**
2004	10.83	3.75	0.68	1.67	21.95	21.33	28.38	100.00	100.00	0.00	0.00		6.88	6.82	0.00
2005	2.04	8.49	0.84	1.27	6.43	5.75	25.19	66.32	16.49	0.00	0.00		3.34	3.83	0.00
2006	13.52	5.40	1.83	5.11	18.60	8.51	100.00	100.00	0.00	0.00	0.00		5.83	5.66	0.00
2007	0.00	1.21	5.59	1.53	37.87	23.28	100.00	100.00	100.00	0.00	0.00		9.35	9.54	0.00
2008	0.03	0.06	0.26	0.14	0.01	0.00	0.00	0.00	0.00	0.00	0.00		0.13	0.13	0.00
2009	0.00	0.00	0.00	0.00	0.42	7.66	53.19	94.56	100.00	100.00	0.00		2.42	2.50	100.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00
2011	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00

Table B37. Total commercial catch-at-age (in 000s of fish) of white hake. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	11.935	704.657	1721.190	1318.864	1047.771	598.294	260.891	40.002	22.950	9.977	12.678		5749.209	5737.274	22.655
1990	26.265	708.689	3646.970	2516.495	1335.412	389.855	85.581	32.752	13.861	8.209	17.229		8781.319	8755.054	25.438
1991	19.743	417.288	410.848	1339.447	1337.178	760.057	176.123	40.613	14.854	8.796	26.316		4551.264	4531.521	35.112
1992	60.365	200.935	346.926	2800.851	2152.040	812.078	364.664	179.515	41.159	10.670	17.194		6986.396	6926.031	27.864
1993	10.046	1446.219	2533.121	2168.931	2340.345	883.467	305.951	101.477	12.655	7.504	13.647		9823.362	9813.315	21.151
1994	0.891	165.092	350.192	1075.562	1142.291	607.259	258.338	87.157	28.960	8.921	13.184		3737.847	3736.956	22.106
1995	0.000	105.715	470.224	1864.686	790.500	335.624	171.658	29.206	24.542	18.331	5.839		3816.325	3816.325	24.170
1996	0.000	44.522	138.835	566.763	529.220	425.035	260.671	68.822	14.591	7.674	7.041		2063.176	2063.176	14.715
1997	0.000	10.826	152.295	122.597	237.128	324.886	195.546	80.458	21.720	8.520	5.135		1159.110	1159.110	13.654
1998	5.700	60.787	213.954	142.486	200.748	192.924	167.853	97.697	38.063	15.681	6.475		1142.368	1136.669	22.157
1999	138.022	1524.689	830.616	362.074	279.935	289.884	172.422	98.442	73.698	23.181	12.478		3805.441	3667.419	35.659
2000	5.560	30.455	113.754	133.143	264.809	272.019	169.849	86.240	92.016	70.757	16.228		1254.829	1249.269	86.985
2001	0.316	27.763	162.883	388.145	378.075	249.338	218.729	117.685	69.861	39.697	14.554		1667.046	1666.730	54.252
2002	18.061	18.508	86.469	253.395	437.733	233.756	186.818	93.915	41.288	10.549	3.842		1384.334	1366.273	14.391
2003	**117.285**	**422.069**	**242.179**	**118.860**	**176.789**	**246.638**	**271.241**	**211.850**	**115.717**	**58.986**	**17.075**		**1998.690**	**1881.404**	**76.062**
2004	18.428	91.284	74.699	91.917	99.526	197.577	171.760	141.639	84.835	45.475	27.464		1044.604	1026.176	72.939
2005	291.773	63.178	32.398	49.454	108.255	135.381	104.074	135.628	81.036	26.201	56.789		1084.168	792.395	82.991
2006	9.625	78.710	39.434	45.442	56.210	73.470	118.612	57.842	52.356	16.233	27.257		575.190	565.566	43.490
2007	8.105	20.031	25.900	64.523	63.804	56.477	74.419	49.315	31.427	13.903	20.751		428.655	420.550	34.654
2008	71.867	73.445	83.463	165.434	141.013	65.308	85.857	40.229	24.762	10.355	7.736		769.470	697.604	18.091
2009	33.339	44.284	57.326	95.238	141.180	125.434	110.279	62.931	40.426	7.288	24.610		742.334	708.995	31.898
2010	6.304	18.658	34.556	92.582	143.000	127.740	85.036	35.767	27.536	14.716	39.168		625.064	618.760	53.884
2011	3.250	12.877	20.112	75.819	161.054	148.220	148.544	85.615	55.143	28.031	42.083		780.748	777.498	70.114

Table B38. Total commercial catch-at-age (in mt) of white hake. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	2.17	99.90	535.33	1110.86	1827.89	1653.97	994.56	215.46	137.05	79.21	129.30		6785.707	6783.538	208.516
1990	1.34	124.14	1184.67	1978.73	2246.52	1140.36	356.32	164.33	94.06	69.08	228.88		7588.437	7587.094	297.960
1991	1.05	60.28	171.58	1392.05	2096.58	1773.56	584.12	168.10	90.30	79.73	301.43		6718.766	6717.716	381.159
1992	3.35	21.43	135.38	2378.42	2980.26	2029.29	1448.69	882.22	240.00	84.08	211.12		10414.245	10410.897	295.200
1993	0.43	179.28	692.69	1924.23	3733.44	2298.51	1122.04	408.86	76.70	54.73	175.44		10666.357	10665.929	230.169
1994	0.04	21.36	105.33	867.68	1706.20	1583.56	977.12	424.73	197.57	65.85	141.99		6091.430	6091.389	207.846
1995	0.00	16.04	237.93	1860.50	1281.37	785.65	511.50	122.64	137.64	96.83	71.39		5121.494	5121.494	168.217
1996	0.00	5.96	46.89	466.64	891.62	1094.86	884.39	282.51	96.23	44.04	71.77		3884.922	3884.922	115.812
1997	0.00	1.60	41.93	98.72	408.98	830.03	687.40	360.83	129.12	58.61	48.49		2665.708	2665.708	107.101
1998	0.11	8.38	57.13	128.24	401.50	582.38	705.60	466.66	234.84	108.08	54.02		2746.950	2746.836	162.106
1999	4.92	163.80	268.91	251.11	471.68	713.91	643.40	478.88	465.92	168.55	110.12		3741.200	3736.284	278.664
2000	0.24	3.56	25.25	82.41	453.50	693.99	567.06	405.31	577.35	482.64	147.01		3438.314	3438.076	629.645
2001	0.05	6.57	37.89	446.30	650.65	641.32	824.63	596.55	427.14	277.51	130.88		4039.492	4039.446	408.393
2002	2.19	5.38	66.17	365.92	975.26	677.33	718.36	418.45	221.21	68.49	30.05		3548.803	3546.613	98.533
2003	**8.31**	**50.98**	**85.15**	**111.68**	**373.08**	**783.44**	**1150.99**	**1106.76**	**679.37**	**391.14**	**146.74**		**4887.641**	**4879.328**	**537.885**
2004	1.44	17.97	30.34	73.08	191.85	671.87	732.87	835.14	576.14	356.84	233.56		3721.118	3719.676	590.404
2005	20.96	10.84	16.75	45.79	206.83	380.91	420.84	629.06	473.75	187.77	455.38		2848.879	2827.917	643.155
2006	1.01	16.26	13.62	46.01	97.79	222.49	476.91	267.38	280.06	133.86	298.83		1854.229	1853.215	432.692
2007	0.66	4.24	11.62	85.67	167.67	244.81	348.65	242.36	171.85	97.29	246.98		1621.803	1621.141	344.265
2008	6.17	11.15	33.95	158.09	293.66	219.59	342.71	193.90	131.15	65.27	95.41		1551.040	1544.870	160.678
2009	2.49	7.47	28.38	98.43	247.03	343.19	443.84	297.01	209.74	49.91	146.55		1874.024	1871.539	196.452
2010	0.63	3.88	16.65	136.36	366.78	361.27	345.26	179.77	162.38	94.95	346.55		2014.478	2013.850	441.494
2011	0.23	2.21	9.22	120.15	405.45	490.16	598.13	427.51	362.73	216.40	406.67		3038.871	3038.638	623.068

Table B39a. Total commercial mean weights-at-age of white hake. The values in bold were computed using a pooled ALK. The 1989-2011 average was used for 1963-1988.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	0.182	0.142	0.311	0.842	1.745	2.764	3.812	5.386	5.972	7.939	10.199		1.180	1.182	9.204
1990	0.051	0.175	0.325	0.786	1.682	2.925	4.164	5.017	6.785	8.415	13.284		0.864	0.867	11.713
1991	0.053	0.144	0.418	1.039	1.568	2.333	3.317	4.139	6.079	9.064	11.454		1.476	1.482	10.855
1992	0.055	0.107	0.390	0.849	1.385	2.499	3.973	4.914	5.831	7.880	12.279		1.491	1.503	10.594
1993	0.043	0.124	0.273	0.887	1.595	2.602	3.667	4.029	6.061	7.293	12.856		1.086	1.087	10.882
1994	0.045	0.129	0.301	0.807	1.494	2.608	3.782	4.873	6.822	7.382	10.770		1.630	1.630	9.402
1995		0.152	0.506	0.998	1.621	2.341	2.980	4.199	5.609	5.282	12.226		1.342	1.342	6.960
1996		0.134	0.338	0.823	1.685	2.576	3.393	4.105	6.595	5.739	10.193		1.883	1.883	7.870
1997		0.148	0.275	0.805	1.725	2.555	3.515	4.485	5.945	6.880	9.443		2.300	2.300	7.844
1998	0.020	0.138	0.267	0.900	2.000	3.019	4.204	4.777	6.170	6.892	8.343		2.405	2.417	7.316
1999	0.036	0.107	0.324	0.694	1.685	2.463	3.732	4.865	6.322	7.271	8.825		0.983	1.019	7.815
2000	0.043	0.117	0.222	0.619	1.713	2.551	3.339	4.700	6.274	6.821	9.059		2.740	2.752	7.239
2001	0.145	0.237	0.233	1.150	1.721	2.572	3.770	5.069	6.114	6.991	8.992		2.423	2.424	7.528
2002	0.121	0.291	0.765	1.444	2.228	2.898	3.845	4.456	5.358	6.492	7.820		2.564	2.596	6.847
2003	**0.071**	**0.121**	**0.352**	**0.940**	**2.110**	**3.176**	**4.243**	**5.224**	**5.871**	**6.631**	**8.594**		**2.445**	**2.593**	**7.072**
2004	0.078	0.197	0.406	0.795	1.928	3.401	4.267	5.896	6.791	7.847	8.504		3.562	3.625	8.094
2005	0.072	0.172	0.517	0.926	1.911	2.814	4.044	4.638	5.846	7.167	8.019		2.628	3.569	7.750
2006	0.105	0.207	0.345	1.012	1.740	3.028	4.021	4.623	5.349	8.246	10.964		3.224	3.277	9.949
2007	0.082	0.212	0.449	1.328	2.628	4.335	4.685	4.914	5.468	6.998	11.902		3.783	3.855	9.934
2008	0.086	0.152	0.407	0.956	2.083	3.362	3.992	4.820	5.296	6.303	12.332		2.016	2.215	8.881
2009	0.075	0.169	0.495	1.033	1.750	2.736	4.025	4.720	5.188	6.848	5.955		2.525	2.640	6.159
2010	0.100	0.208	0.482	1.473	2.565	2.828	4.060	5.026	5.897	6.452	8.848		3.223	3.255	8.193
2011	0.072	0.172	0.458	1.585	2.518	3.307	4.027	4.993	6.578	7.720	9.663		3.892	3.908	8.887
1989-2011 average		0.163	0.385	0.987	1.873	2.856	3.863	4.777	6.010						8.565

Table B39b. January 1 weights at age calculated using the Rivard method. The 1989-2011 average was used for the 1963-1988 values.

	0	1	2	3	4	5	6	7	8
1989	0.094	0.196	0.596	1.348	2.252	3.323	4.799	5.671	9.204
1990	0.113	0.215	0.494	1.190	2.259	3.393	4.373	6.045	11.713
1991	0.088	0.271	0.581	1.110	1.981	3.115	4.152	5.523	10.855
1992	0.067	0.237	0.596	1.200	1.980	3.045	4.037	4.913	10.594
1993	0.080	0.171	0.588	1.164	1.898	3.027	4.001	5.457	10.882
1994	0.065	0.193	0.469	1.151	2.040	3.137	4.227	5.243	9.402
1995	0.102	0.256	0.548	1.144	1.870	2.788	3.985	5.228	6.960
1996	0.094	0.227	0.645	1.297	2.044	2.818	3.498	5.262	7.870
1997	0.110	0.192	0.522	1.192	2.075	3.009	3.901	4.940	7.844
1998	0.090	0.199	0.498	1.269	2.282	3.277	4.098	5.261	7.316
1999	0.074	0.212	0.431	1.232	2.220	3.357	4.522	5.496	7.815
2000	0.083	0.154	0.448	1.090	2.073	2.868	4.188	5.525	7.239
2001	0.132	0.165	0.505	1.032	2.099	3.101	4.114	5.361	7.528
2002	0.267	0.426	0.580	1.601	2.233	3.145	4.099	5.212	6.847
2003	0.038	0.318	0.830	1.736	2.660	3.509	4.483	5.115	7.072
2004	0.240	0.376	0.751	1.467	2.732	3.838	5.007	5.958	8.095
2005	0.121	0.400	1.049	1.762	2.592	3.802	4.639	5.873	7.750
2006	0.141	0.244	0.723	1.269	2.406	3.364	4.324	4.981	9.949
2007	0.153	0.305	0.677	1.631	2.746	3.767	4.445	5.028	9.934
2008	0.088	0.294	0.655	1.663	2.972	4.160	4.752	5.101	8.881
2009	0.097	0.263	0.634	1.305	2.393	3.679	4.340	5.001	6.158
2010	0.140	0.283	0.818	1.591	2.245	3.341	4.498	5.275	8.193
2011	0.096	0.309	0.874	1.926	2.913	3.375	4.502	5.750	8.887
2012	0.111	0.285	0.775	1.607	2.517	3.465	4.447	5.342	7.746
1989-2011 average	0.112	0.258	0.637	1.374	2.312	3.321	4.310	5.357	8.531

Table B39c. Rivard weights at age interpolated for the time of spawning (April)..

	1	2	3	4	5	6	7	8	9+
1989	0.108	0.228	0.669	1.469	2.411	3.479	4.987	5.770	9.204
1990	0.131	0.247	0.577	1.336	2.462	3.632	4.578	6.282	11.713
1991	0.103	0.313	0.705	1.246	2.092	3.181	4.147	5.702	10.855
1992	0.078	0.280	0.670	1.259	2.139	3.327	4.311	5.202	10.594
1993	0.092	0.200	0.675	1.293	2.109	3.227	4.010	5.652	10.882
1994	0.082	0.224	0.562	1.256	2.214	3.339	4.432	5.724	9.402
1995	0.116	0.321	0.669	1.285	2.016	2.850	4.055	5.352	6.960
1996	0.105	0.259	0.700	1.415	2.208	2.998	3.689	5.674	7.870
1997	0.122	0.216	0.603	1.348	2.224	3.169	4.087	5.255	7.844
1998	0.104	0.219	0.606	1.477	2.505	3.561	4.313	5.548	7.316
1999	0.084	0.244	0.505	1.367	2.298	3.477	4.634	5.758	7.815
2000	0.093	0.174	0.499	1.268	2.222	3.017	4.352	5.764	7.239
2001	0.160	0.185	0.665	1.224	2.246	3.310	4.411	5.601	7.528
2002	0.274	0.518	0.786	1.787	2.436	3.363	4.215	5.260	6.847
2003	0.055	0.327	0.853	1.847	2.821	3.740	4.719	5.355	7.072
2004	0.261	0.552	0.971	1.725	2.988	4.089	5.289	6.224	8.095
2005	0.136	0.436	1.007	1.811	2.664	3.881	4.639	5.864	7.750
2006	0.160	0.274	0.809	1.410	2.597	3.570	4.421	5.101	9.949
2007	0.171	0.347	0.847	1.912	3.198	4.051	4.596	5.170	9.934
2008	0.106	0.327	0.743	1.793	3.097	4.103	4.775	5.166	8.881
2009	0.116	0.315	0.735	1.448	2.507	3.791	4.463	5.062	6.158
2010	0.160	0.338	0.995	1.866	2.425	3.566	4.668	5.475	8.193
2011	0.117	0.352	1.066	2.106	3.039	3.580	4.660	6.014	8.887
1989-2011 average	0.128	0.300	0.736	1.519	2.475	3.491	4.454	5.564	8.565

Table B40. Percentage by age of catch-at-age (000s) that were filled out to account for missing ages-at-length. The total is the percentage of the entire catch-at-age.

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	100.00	14.08	4.23	0.49	6.09	5.46	14.59	59.87	56.93	100.00	71.65		6.91	6.78	84.13
1990	5.08	1.58	0.08	0.00	0.01	0.48	12.60	27.65	75.74	83.09	88.72		1.01	1.00	86.91
1991	0.00	0.03	0.08	0.00	0.00	0.05	1.46	5.06	43.26	92.10	90.10		1.05	1.06	90.60
1992	0.00	2.72	2.31	0.00	0.00	0.27	2.61	4.30	12.73	63.00	95.97		0.88	0.88	83.34
1993	0.00	0.01	0.00	0.00	0.08	1.64	8.65	29.45	100.00	77.12	100.00		1.36	1.36	91.88
1994	0.00	0.46	0.00	0.03	1.09	6.65	15.27	30.99	80.36	100.00	100.00		4.92	4.92	100.00
1995	0.00	1.00	0.01	0.00	0.00	0.90	6.80	30.81	19.24	1.25	76.47		0.93	0.93	19.42
1996	0.00	0.00	0.00	0.00	0.06	1.26	7.32	17.03	33.09	59.99	76.07		2.79	2.79	67.69
1997	0.00	0.87	0.68	0.55	0.51	3.43	11.65	20.43	42.36	56.87	72.55		6.87	6.87	62.76
1998	33.33	10.50	1.56	0.57	13.08	39.40	62.45	55.11	85.98	100.00	100.00		35.79	35.79	100.00
1999	0.00	0.00	0.00	0.48	3.81	0.98	6.58	13.68	18.30	70.27	80.88		4.14	4.24	73.98
2000	35.63	0.55	0.00	0.00	0.74	6.92	24.89	29.33	18.66	12.76	78.79		12.20	12.17	25.08
2001	100.00	8.13	0.61	0.01	0.79	11.93	33.27	56.54	79.15	86.83	97.90		19.51	19.50	89.80
2002	4.10	2.60	1.86	3.53	2.85	10.86	44.09	68.56	83.66	100.00	100.00		18.68	18.75	100.00
2003	**0.00**	**0.00**	**0.01**	**0.23**	**0.02**	**3.49**	**12.19**	**17.47**	**48.32**	**35.30**	**41.95**		**12.50**	**12.77**	**36.79**
2004	15.82	5.81	2.42	5.12	39.24	32.73	77.17	100.00	91.79	83.91	100.00		51.32	51.96	89.97
2005	7.57	9.61	2.75	14.52	9.63	16.30	51.78	28.82	33.24	68.17	44.95		27.34	29.32	52.28
2006	12.66	12.07	2.71	7.44	23.52	44.31	50.94	74.61	53.98	100.00	92.12		48.58	48.76	95.06
2007	0.00	1.73	10.83	0.65	0.53	0.10	0.02	0.02	0.00	0.00	19.64		1.40	1.40	11.76
2008	0.05	0.07	0.35	0.21	0.67	13.68	8.15	2.36	0.71	0.68	18.06		3.82	3.98	8.11
2009	0.00	0.00	0.00	0.00	3.47	11.05	30.47	56.44	58.94	100.00	14.21		19.65	19.99	33.80
2010	0.00	0.00	0.00	0.00	0.00	0.81	6.16	31.21	54.48	54.61	48.02		10.96	11.00	49.82
2011	0.00	0.00	0.00	0.00	0.20	0.00	11.45	35.84	70.61	81.74	69.12		18.87	18.89	74.17

Table B41. Percentage by age of catch-at-age (mt) that were filled out to account for missing ages-at-length. The total is the percentage of the entire catch-at-age

	0	1	2	3	4	5	6	7	8	9	10+		Total	1+	9+
1989	100.00	19.29	2.81	0.69	5.13	5.08	15.81	56.79	61.05	100.00	79.94		11.32	11.29	87.56
1990	3.17	0.44	0.01	0.00	0.04	0.83	16.80	32.15	72.30	80.75	89.67		5.97	5.97	87.60
1991	0.00	0.01	0.01	0.00	0.00	0.10	2.63	8.09	54.42	92.39	92.20		6.42	6.42	92.24
1992	0.00	1.20	0.53	0.00	0.00	0.46	3.26	4.70	15.44	68.39	96.18		3.81	3.81	88.27
1993	0.00	0.00	0.00	0.00	0.17	2.53	10.52	35.28	100.00	78.23	100.00		5.83	5.83	94.82
1994	0.00	0.06	0.00	0.07	1.70	7.52	17.63	33.49	79.27	100.00	100.00		13.59	13.59	100.00
1995	0.00	0.21	0.00	0.00	0.00	1.59	9.54	32.62	23.40	1.63	76.93		3.71	3.71	33.59
1996	0.00	0.00	0.00	0.00	0.13	1.95	9.73	20.21	29.66	77.63	80.73		7.37	7.37	79.55
1997	0.00	1.60	0.66	0.17	1.24	5.20	15.78	24.81	45.14	58.82	74.46		14.09	14.09	65.90
1998	13.30	3.47	0.36	1.36	19.04	45.67	63.29	58.81	84.56	100.00	100.00		51.93	51.93	100.00
1999	0.00	0.00	0.00	0.88	2.77	1.54	10.55	19.38	24.31	70.14	81.96		13.60	13.61	74.81
2000	27.38	0.18	0.00	0.00	1.65	10.28	32.19	32.54	19.78	14.13	78.47		20.10	20.10	29.15
2001	100.00	5.20	0.94	0.00	1.66	18.52	40.56	58.55	79.57	86.98	97.96		37.72	37.72	90.50
2002	1.05	1.55	1.17	2.26	2.40	15.71	51.88	76.54	90.22	100.00	100.00		31.84	31.86	100.00
2003	**0.00**	**0.00**	**0.01**	**0.11**	**0.00**	**4.77**	**13.39**	**18.17**	**48.50**	**33.64**	**42.02**		**18.73**	**18.76**	**35.93**
2004	10.83	3.75	0.66	12.02	43.96	34.48	83.27	100.00	90.35	82.63	100.00		75.79	75.81	89.50
2005	2.04	8.49	1.32	19.53	9.88	21.73	58.37	30.98	36.03	75.51	59.65		39.96	40.24	64.28
2006	13.52	5.40	1.66	6.87	28.46	53.01	56.37	82.64	64.79	100.00	96.44		67.06	67.09	97.54
2007	0.00	1.21	4.12	0.91	16.69	24.29	7.27	1.04	0.61	0.38	23.33		10.83	10.84	16.85
2008	0.03	0.06	0.24	0.07	0.91	12.10	6.56	1.66	0.52	0.32	21.42		4.93	4.95	12.85
2009	0.00	0.00	0.00	0.00	5.70	14.12	35.00	61.91	66.96	100.00	24.90		33.54	33.59	43.98
2010	0.00	0.00	0.00	0.00	0.00	1.45	8.78	38.74	62.66	66.73	75.67		26.44	26.44	73.75
2011	0.00	0.00	0.00	0.00	0.43	0.00	15.11	42.27	72.43	84.93	82.43		34.70	34.70	83.29

Table B42. Otter trawl landings (MT), days fished (DF) and landings per unit effort (LPUE for all trips landings white hake that had effort, trips for which white hake accounted for 40% of the landings, 60% of the landings and 80% of the landings.

		All Trips				40% Trips				60% Trips				80% Trips	
Year	MT	DF	LPUE		MT	DF	LPUE		MT	DF	LPUE		MT	DF	LPUE
1975	678	2,737	0.25		29	11	2.62		13	5	2.63		5	1	7.57
1976	749	2,304	0.32		43	7	6.39		35	4	9.62		35	4	9.62
1977	877	2,664	0.33		14	5	3.08		3	1	5.93				
1978	898	2,819	0.32		21	3	8.54								
1979	888	3,761	0.24		31	7	4.20		15	1	11.28				
1980	1,025	4,352	0.24		14	5	3.08		6	2	3.50		6	2	3.50
1981	1,535	4,444	0.35		87	31	2.85		32	5	6.34				
1982	1,922	6,125	0.31		75	35	2.17		3	1	2.62				
1983	2,449	6,778	0.36		328	144	2.29		75	13	5.62				
1984	2,700	7,760	0.35		205	144	1.42		32	14	2.28		5	3	2.03
1985	3,587	9,194	0.39		605	353	1.72		110	46	2.37				
1986	2,995	8,819	0.34		509	349	1.46		56	28	2.00		17	3	6.46
1987	2,912	8,957	0.33		662	620	1.07		134	91	1.47		19	15	1.26
1988	2,463	8,258	0.30		688	701	0.98		106	72	1.49		15	8	1.83
1989	1,312	6,319	0.21		268	274	0.98		53	38	1.41		19	7	2.75
1990	1,760	6,540	0.27		490	321	1.53		212	78	2.72		10	8	1.20
1991	1,924	7,021	0.27		441	227	1.94		232	41	5.68		176	6	29.40
1992	2,638	7,788	0.34		814	808	1.01		268	166	1.62		7	3	2.58
1993	2,423	7,524	0.32		791	757	1.05		218	129	1.69		35	17	2.09
1994	1,296	6,887	0.19		113	128	0.88		13	9	1.45		1	2	0.76
1995	1,481	8,583	0.17		230	260	0.88		52	32	1.64		1	4	0.28
1996	1,304	7,141	0.18		119	127	0.93		16	19	0.82		2	8	0.19
1997	751	5,256	0.14		30	28	1.06		7	5	1.45				
1998	801	5,420	0.15		75	68	1.10		11	2	4.41		11	2	4.41
1999	946	5,977	0.16		62	45	1.39		8	1	9.97		6	1	12.71
2000	1,153	5,519	0.21		152	102	1.50		27	6	4.68		6	1	7.35
2001	1,716	6,227	0.28		172	99	1.74		50	16	3.20		24	4	6.03
2002	1,657	5,482	0.30		227	118	1.93		35	11	3.12		13	5	2.80
2003	2,056	5,145	0.40		414	160	2.59		177	31	5.79		84	7	12.17
2004	1,735	4,849	0.36		379	174	2.18		151	69	2.19		43	25	1.71
2005	1,348	4,307	0.31		274	137	2.00		77	23	3.28		0	0	2.19
2006	977	4,029	0.24		41	45	0.91		5	8	0.69		2	3	0.76
2007	796	3,774	0.21		26	37	0.72		2	7	0.30		1	1	0.77
2008	650	3,206	0.20		16	19	0.84		5	4	1.38		1	2	0.38
2009	873	3,265	0.27		45	65	0.69		3	11	0.31		2	6	0.30
2010	1,049	2,753	0.38		110	71	1.55		25	14	1.79		1	3	0.26
2011	2,063	3,657	0.56		425	248	1.72		87	53	1.64		12	20	0.63
average	1,578	5,558	0.28		244	182	1.97		65	29	3.29		19	6	4.28

Table B43. Sink gill net landings (MT), days fished (DF) and landings per unit effort (LPUE for all trips landings white hake that had effort, trips for which white hake accounted for 40% of the landings, 60% of the landings and 80% of the landings.

		All Trips				40% Trips				60% Trips				80% Trips	
Year	MT	DF	LPUE		MT	DF	LPUE		Year	MT	DF		MT	DF	LPUE
1975	119	72	1.64		72	27	2.70		28	8	3.42		12	3	4.79
1976	131	95	1.37		87	24	3.62		49	12	4.09		13	3	4.08
1977	158	150	1.05		96	36	2.67		33	9	3.72		2	1	2.63
1978	204	183	1.12		136	40	3.44		117	29	4.01		10	3	3.11
1979	95	132	0.72		27	12	2.27		23	10	2.36		1	0	4.94
1980	13	31	0.42		5	2	3.02		1	0	2.23				
1981	31	22	1.42		28	7	4.06		27	5	5.44		23	4	5.95
1982	101	115	0.87		67	24	2.82		43	13	3.35		21	5	4.21
1983	117	280	0.42		57	27	2.11		34	12	2.82		12	3	4.87
1984	162	334	0.49		90	44	2.06		40	11	3.82				
1985	154	283	0.54		74	51	1.45		26	13	2.07		8	3	2.58
1986	86	341	0.25		43	33	1.29		22	17	1.26		7	6	1.23
1987	74	371	0.20		3	13	0.26		1	2	0.30				
1988	177	500	0.35		90	57	1.56		35	16	2.19		5	1	10.45
1989	273	372	0.73		226	123	1.83		156	60	2.59		50	16	3.21
1990	350	573	0.61		221	162	1.37		80	56	1.43		5	3	1.76
1991	228	554	0.41		85	88	0.96		23	15	1.59		3	1	3.24
1992	355	842	0.42		218	206	1.06		75	53	1.43		4	1	3.45
1993	240	823	0.29		132	157	0.84		46	44	1.03		0	2	0.09
1994	319	2033	0.16		111	87	1.28		36	24	1.48		7	9	0.72
1995	611	4146	0.15		277	127	2.19		133	49	2.70		25	14	1.72
1996	519	3487	0.15		244	128	1.90		106	51	2.07		14	10	1.52
1997	358	2971	0.12		107	99	1.08		56	21	2.61		19	6	3.36
1998	430	2406	0.18		157	85	1.84		49	21	2.38		7	5	1.44
1999	642	3161	0.20		322	123	2.63		126	31	4.11		35	7	5.15
2000	701	3782	0.19		303	91	3.35		142	32	4.39		26	8	3.29
2001	733	4702	0.16		368	119	3.09		155	33	4.76		15	3	4.29
2002	586	4020	0.15		347	173	2.00		110	39	2.79		25	7	3.57
2003	1027	4434	0.23		693	340	2.04		399	146	2.73		99	26	3.82
2004	659	3869	0.17		342	227	1.51		167	74	2.26		54	14	3.97
2005	318	3595	0.09		94	128	0.73		39	63	0.63		9	40	0.22
2006	209	2990	0.07		37	71	0.52		15	38	0.40		1	17	0.06
2007	298	3828	0.08		33	74	0.44		6	14	0.43		0	1	0.61
2008	286	3787	0.08		30	49	0.60		14	17	0.83		2	9	0.26
2009	303	3747	0.08		88	92	0.96		17	39	0.43		3	26	0.13
2010	311	2529	0.12		134	77	1.75		68	41	1.68		23	17	1.36
2011	544	3673	0.15		164	214	0.77		35	50	0.69		2	4	0.54
average	322	1871	0.43		152	93	1.63		93	43	2.08		16	8	2.84

Table B44. White hake otter trawl effort (days fished) GLM standardization Standard: Year = 75; Area = 515; Qtr = 3; TC = 32. Area 522 includes 521,522,523(561), Area 525 includes 524(562) 525,526.

```
whhake glm log(cpue) using df               13:58 Wednesday, January 23, 2013   1
             Factors are year area qtr tc

                 The GENMOD Procedure

                  Model Information

            Data Set                WORK.A2
            Distribution             Normal
            Link Function          Identity
            Dependent Variable     lncpuedf


       Number of Observations Read       77369
       Number of Observations Used       77369


                Class Level Information

Class      Levels    Values

year           37    1976 1977 1978 1979 1980 1981 1982 1983 1984 1985
                     1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
                     1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
                     2006 2007 2008 2009 2010 2011 9999
AREA            7    511 512 513 514 522 525 999
qtr             4    1 2 4 99
tc              3    2 4 99


           Criteria For Assessing Goodness Of Fit

    Criterion                    DF           Value        Value/DF

    Deviance                   77E3     160425.5716          2.0748
    Scaled Deviance            77E3      77369.0000          1.0006
    Pearson Chi-Square         77E3     160425.5716          2.0748
    Scaled Pearson X2          77E3      77369.0000          1.0006
    Log Likelihood                     -137992.2919
    Full Log Likelihood                -137992.2919
    AIC (smaller is better)             276082.5838
    AICC (smaller is better)            276082.6472
    BIC (smaller is better)             276536.1446


Algorithm converged.


                 Analysis Of Maximum Likelihood Parameter Estimates

                                  Standard     Wald 95% Confidence          Wald
Parameter           DF    Estimate       Error           Limits            Chi-Square    Pr > ChiSq

Intercept            1     -0.6764      0.0414     -0.7576     -0.5952        266.60        <.0001
year        1976     1      0.1707      0.0545      0.0639      0.2776          9.81        0.0017
year        1977     1      0.3718      0.0516      0.2706      0.4729         51.87        <.0001
year        1978     1      0.0080      0.0526     -0.0950      0.1110          0.02        0.8790
year        1979     1     -0.2458      0.0507     -0.3451     -0.1464         23.51        <.0001
```

Table B44. Cont.

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whhake glm log(cpue) using df             13:58 Wednesday, January 23, 2013   2
        Factors are year area qtr tc

            The GENMOD Procedure

  Analysis Of Maximum Likelihood Parameter Estimates
```

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
year	1980	1	-0.2848	0.0493	-0.3813	-0.1882	33.43	<.0001
year	1981	1	-0.2130	0.0523	-0.3154	-0.1105	16.61	<.0001
year	1982	1	-0.3104	0.0486	-0.4057	-0.2152	40.80	<.0001
year	1983	1	-0.2374	0.0480	-0.3314	-0.1434	24.50	<.0001
year	1984	1	-0.1745	0.0481	-0.2688	-0.0802	13.15	0.0003
year	1985	1	-0.2314	0.0466	-0.3228	-0.1401	24.65	<.0001
year	1986	1	-0.5602	0.0474	-0.6530	-0.4673	139.82	<.0001
year	1987	1	-0.3763	0.0471	-0.4686	-0.2839	63.74	<.0001
year	1988	1	-0.6073	0.0480	-0.7013	-0.5132	160.21	<.0001
year	1989	1	-0.9120	0.0511	-1.0121	-0.8119	318.73	<.0001
year	1990	1	-0.9208	0.0505	-1.0198	-0.8219	332.61	<.0001
year	1991	1	-0.7914	0.0501	-0.8897	-0.6932	249.29	<.0001
year	1992	1	-0.4431	0.0493	-0.5397	-0.3464	80.76	<.0001
year	1993	1	-0.6836	0.0496	-0.7809	-0.5864	189.87	<.0001
year	1994	1	-1.2138	0.0493	-1.3105	-1.1171	605.42	<.0001
year	1995	1	-1.3145	0.0479	-1.4083	-1.2206	753.13	<.0001
year	1996	1	-1.2266	0.0487	-1.3221	-1.1311	633.60	<.0001
year	1997	1	-1.3391	0.0508	-1.4388	-1.2395	694.26	<.0001
year	1998	1	-1.3828	0.0494	-1.4796	-1.2860	783.43	<.0001
year	1999	1	-1.2827	0.0481	-1.3770	-1.1884	710.05	<.0001
year	2000	1	-0.9925	0.0481	-1.0867	-0.8983	426.17	<.0001
year	2001	1	-0.7195	0.0472	-0.8120	-0.6269	232.17	<.0001
year	2002	1	-0.8022	0.0476	-0.8956	-0.7089	283.54	<.0001
year	2003	1	-0.7670	0.0474	-0.8600	-0.6740	261.48	<.0001
year	2004	1	-0.8454	0.0488	-0.9409	-0.7498	300.59	<.0001
year	2005	1	-0.8721	0.0496	-0.9693	-0.7748	308.65	<.0001
year	2006	1	-0.8869	0.0518	-0.9885	-0.7853	292.86	<.0001
year	2007	1	-0.9806	0.0519	-1.0824	-0.8788	356.45	<.0001
year	2008	1	-1.0704	0.0523	-1.1729	-0.9679	419.10	<.0001
year	2009	1	-0.8597	0.0517	-0.9611	-0.7584	276.53	<.0001
year	2010	1	-0.2796	0.0528	-0.3830	-0.1761	28.07	<.0001
year	2011	1	0.0182	0.0471	-0.0742	0.1106	0.15	0.6993
year	9999	0	0.0000	0.0000	0.0000	0.0000	.	.
AREA	511	1	0.5010	0.0482	0.4065	0.5955	108.00	<.0001
AREA	512	1	0.3985	0.0242	0.3510	0.4460	270.40	<.0001
AREA	513	1	-0.7858	0.0184	-0.8219	-0.7496	1814.78	<.0001
AREA	514	1	-1.1818	0.0199	-1.2208	-1.1429	3535.11	<.0001
AREA	522	1	-0.9262	0.0162	-0.9581	-0.8944	3251.09	<.0001
AREA	525	1	-2.5033	0.0273	-2.5568	-2.4498	8409.97	<.0001
AREA	999	0	0.0000	0.0000	0.0000	0.0000	.	.
qtr	1	1	-0.3469	0.0156	-0.3775	-0.3164	496.44	<.0001
qtr	2	1	-0.5313	0.0142	-0.5591	-0.5035	1398.32	<.0001
qtr	4	1	-0.0254	0.0140	-0.0528	0.0019	3.32	0.0683
qtr	99	0	0.0000	0.0000	0.0000	0.0000	.	.
tc	2	1	-0.8871	0.0144	-0.9154	-0.8588	3770.56	<.0001
tc	4	1	0.4565	0.0133	0.4304	0.4825	1179.82	<.0001
tc	99	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		1	1.4400	0.0037	1.4328	1.4472		

NOTE: The scale parameter was estimated by maximum likelihood.

Table B45. White hake otter trawl effort (days fished) GLM standardization for directed (>40% white hake) trips. Standard: Year = 75; Area = 515; Qtr = 3; TC = 32. Area 522 includes 521,522,523(561), Area 525 includes 524(562) 525,526.

```
                           whhake glm log(cpue) using df               14:00 Wednesday, January 23, 2013   1
                            Factors are year area qtr tc

                                The GENMOD Procedure

                                 Model Information

                           Data Set                  WORK.A2
                           Distribution               Normal
                           Link Function            Identity
                           Dependent Variable       lncpuedf


                      Number of Observations Read        2284
                      Number of Observations Used        2284


                               Class Level Information

         Class      Levels    Values

         year           37    1976 1977 1978 1979 1980 1981 1982 1983 1984 1985
                              1986 1987 1988 1989 1990 1991 1992 1993 1994 1995
                              1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
                              2006 2007 2008 2009 2010 2011 9999
         AREA            7    511 512 513 514 522 525 999
         qtr             4    1 2 4 99
         tc              3    2 4 99


                         Criteria For Assessing Goodness Of Fit

             Criterion                     DF           Value        Value/DF

             Deviance                    2236       1392.8360          0.6229
             Scaled Deviance             2236       2284.0000          1.0215
             Pearson Chi-Square          2236       1392.8360          0.6229
             Scaled Pearson X2           2236       2284.0000          1.0215
             Log Likelihood                        -2676.0380
             Full Log Likelihood                   -2676.0380
             AIC (smaller is better)                5450.0760
             AICC (smaller is better)               5452.2694
             BIC (smaller is better)                5731.0265


       Algorithm converged.


                      Analysis Of Maximum Likelihood Parameter Estimates

                                     Standard     Wald 95% Confidence          Wald
Parameter           DF    Estimate       Error           Limits            Chi-Square    Pr > ChiSq

Intercept            1      1.1361      0.1977      0.7485      1.5236          33.01        <.0001
year         1976    1     -0.0963      0.3124     -0.7086      0.5160           0.10        0.7578
year         1977    1     -0.0501      0.3527     -0.7414      0.6411           0.02        0.8870
year         1978    1      0.4493      0.3975     -0.3298      1.2285           1.28        0.2584
year         1979    1      0.1197      0.3983     -0.6609      0.9003           0.09        0.7637
```

Table B45. Cont.

whhake glm log(cpue) using df 14:00 Wednesday, January 23, 2013 2

Factors are year area qtr tc

The GENMOD Procedure

Analysis Of Maximum Likelihood Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
year	1980	1	-0.3040	0.3716	-1.0323	0.4243	0.67	0.4133
year	1981	1	-0.1595	0.2902	-0.7283	0.4093	0.30	0.5826
year	1982	1	-0.6389	0.2516	-1.1320	-0.1459	6.45	0.0111
year	1983	1	-0.3558	0.2190	-0.7851	0.0734	2.64	0.1042
year	1984	1	-0.7963	0.2167	-1.2210	-0.3715	13.50	0.0002
year	1985	1	-0.7181	0.2047	-1.1192	-0.3170	12.31	0.0005
year	1986	1	-1.0421	0.2059	-1.4457	-0.6385	25.61	<.0001
year	1987	1	-1.1782	0.2001	-1.5704	-0.7859	34.65	<.0001
year	1988	1	-1.2395	0.2002	-1.6319	-0.8472	38.34	<.0001
year	1989	1	-1.4026	0.2110	-1.8161	-0.9890	44.19	<.0001
year	1990	1	-1.1866	0.2109	-1.5999	-0.7734	31.67	<.0001
year	1991	1	-1.0046	0.2132	-1.4225	-0.5868	22.20	<.0001
year	1992	1	-1.1598	0.1998	-1.5514	-0.7683	33.71	<.0001
year	1993	1	-1.3369	0.2010	-1.7310	-0.9429	44.23	<.0001
year	1994	1	-1.5927	0.2199	-2.0237	-1.1617	52.45	<.0001
year	1995	1	-1.5311	0.2150	-1.9526	-1.1097	50.71	<.0001
year	1996	1	-1.6208	0.2297	-2.0711	-1.1706	49.79	<.0001
year	1997	1	-1.7507	0.2892	-2.3175	-1.1840	36.66	<.0001
year	1998	1	-1.5643	0.2480	-2.0504	-1.0782	39.78	<.0001
year	1999	1	-0.9009	0.2640	-1.4184	-0.3834	11.64	0.0006
year	2000	1	-0.9647	0.2333	-1.4220	-0.5074	17.10	<.0001
year	2001	1	-1.0613	0.2305	-1.5131	-0.6096	21.20	<.0001
year	2002	1	-0.7079	0.2279	-1.1546	-0.2612	9.65	0.0019
year	2003	1	-0.6812	0.2187	-1.1099	-0.2526	9.70	0.0018
year	2004	1	-0.8403	0.2177	-1.2669	-0.4136	14.90	0.0001
year	2005	1	-0.7150	0.2183	-1.1428	-0.2871	10.73	0.0011
year	2006	1	-1.7002	0.2709	-2.2312	-1.1692	39.38	<.0001
year	2007	1	-1.7494	0.2683	-2.2753	-1.2235	42.50	<.0001
year	2008	1	-1.3713	0.2740	-1.9083	-0.8343	25.05	<.0001
year	2009	1	-1.8557	0.2429	-2.3318	-1.3796	58.36	<.0001
year	2010	1	-1.0894	0.2208	-1.5222	-0.6565	24.33	<.0001
year	2011	1	-1.1862	0.2032	-1.5845	-0.7879	34.07	<.0001
year	9999	0	0.0000	0.0000	0.0000	0.0000	.	.
AREA	511	1	0.2372	0.0743	0.0916	0.3828	10.19	0.0014
AREA	512	1	0.0661	0.0530	-0.0377	0.1699	1.56	0.2122
AREA	513	1	-0.0131	0.0609	-0.1326	0.1063	0.05	0.8293
AREA	514	1	0.0705	0.0600	-0.0472	0.1882	1.38	0.2403
AREA	522	1	-0.1382	0.0505	-0.2371	-0.0393	7.50	0.0062
AREA	525	1	-0.5964	0.1883	-0.9655	-0.2274	10.03	0.0015
AREA	999	0	0.0000	0.0000	0.0000	0.0000	.	.
qtr	1	1	0.3289	0.0621	0.2072	0.4506	28.07	<.0001
qtr	2	1	0.2157	0.0472	0.1231	0.3082	20.86	<.0001
qtr	4	1	-0.1543	0.0434	-0.2394	-0.0692	12.64	0.0004
qtr	99	0	0.0000	0.0000	0.0000	0.0000	.	.
tc	2	1	-0.3968	0.0528	-0.5002	-0.2934	56.57	<.0001
tc	4	1	0.2021	0.0398	0.1240	0.2801	25.75	<.0001
tc	99	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		1	0.7809	0.0116	0.7586	0.8039		

NOTE: The scale parameter was estimated by maximum likelihood.

Table B46. White hake landings (mt) used in the GLM, total landings, nominal and standardized effort (days fished-raised to total landings) and landings per day fished (LPUE) for the otter trawl fleet.

			Nominal		Standardized	
year	Landings in GLM	Total OT Landings	Effort	LPUE	Effort	LPUE
1975	658	1368	5469	0.250	2332	0.586
1976	735	1615	4975	0.325	2171	0.744
1977	838	2321	7135	0.325	2901	0.800
1978	881	2183	6819	0.320	2851	0.766
1979	881	2068	8627	0.240	3739	0.553
1980	1003	2675	11248	0.238	5559	0.481
1981	1400	3488	9352	0.373	5233	0.667
1982	1797	3862	11815	0.327	7437	0.519
1983	2288	4866	13134	0.371	8498	0.573
1984	2415	5156	14205	0.363	8934	0.577
1985	3370	5504	14056	0.392	9894	0.556
1986	2786	4670	13779	0.339	9993	0.467
1987	2832	4797	14775	0.325	9405	0.510
1988	2456	3655	12255	0.298	7118	0.514
1989	1312	2548	12275	0.208	6879	0.370
1990	1761	3280	12183	0.269	7335	0.447
1991	1924	3548	12946	0.274	7828	0.453
1992	2638	5191	15325	0.339	8809	0.589
1993	2423	4653	14453	0.322	7876	0.591
1994	1161	2478	13362	0.185	7820	0.317
1995	1349	2406	13846	0.174	8349	0.288
1996	1196	2037	11079	0.184	6600	0.309
1997	684	1266	9004	0.141	4876	0.260
1998	747	1286	8782	0.146	4659	0.276
1999	889	1482	9284	0.160	4348	0.341
2000	1107	1811	8719	0.208	3818	0.474
2001	1649	2421	8788	0.276	4064	0.596
2002	1589	2338	7689	0.304	3311	0.706
2003	1993	2860	7095	0.403	3321	0.861
2004	1652	2403	6710	0.358	3597	0.668
2005	1294	1884	5966	0.316	3090	0.610
2006	927	1317	5439	0.242	3005	0.438
2007	764	1032	4861	0.212	2772	0.372
2008	611	904	4432	0.204	2242	0.403
2009	791	1200	4551	0.264	2369	0.506
2010	975	1388	3630	0.382	1644	0.844
2011	1973	2306	4099	0.562	2002	1.152

Table B47. White hake landings (mt) used in the GLM for directed (>40% white hake) trips, total landings, nominal and standardized effort, and landings per day fished (LPUE) for the otter trawl fleet.

		Nominal		Standardized	
year	Landings in GLM	Effort	LPUE	Effort	LPUE
1975	29	11	2.620	11	2.637
1976	43	7	6.361	7	6.445
1977	14	5	3.075	5	3.021
1978	21	3	8.540	3	7.651
1979	31	7	4.204	6	4.878
1980	14	5	3.075	5	2.917
1981	87	31	2.847	31	2.852
1982	75	35	2.169	38	1.990
1983	328	144	2.286	145	2.257
1984	205	145	1.420	149	1.378
1985	605	353	1.716	370	1.637
1986	509	349	1.458	435	1.170
1987	663	621	1.068	650	1.019
1988	688	701	0.982	747	0.921
1989	269	274	0.981	312	0.861
1990	490	321	1.527	374	1.310
1991	441	227	1.943	225	1.963
1992	814	808	1.008	799	1.020
1993	791	757	1.045	765	1.034
1994	114	128	0.891	154	0.737
1995	254	263	0.967	288	0.883
1996	119	128	0.932	154	0.770
1997	30	28	1.061	33	0.895
1998	75	68	1.106	79	0.950
1999	62	45	1.388	54	1.153
2000	152	102	1.499	126	1.212
2001	172	99	1.742	123	1.393
2002	228	118	1.931	148	1.542
2003	446	160	2.785	205	2.176
2004	379	173	2.186	229	1.652
2005	274	137	2.002	174	1.571
2006	41	45	0.911	51	0.806
2007	26	36	0.722	38	0.689
2008	20	20	1.037	18	1.159
2009	45	65	0.695	76	0.598
2010	110	70	1.568	87	1.262
2011	425	247	1.725	313	1.360

Table B48. White hake sink gill net effort (days fished) GLM standardization Standard: Year = 75; Area = 515; Qtr = 3; TC = 32. Area 522 includes 521,522,523(561), Area 525 includes 524(562) 525,526.

```
                         whhake glm log(cpue) using df                  13:07 Friday, January 25, 2013   1
                                 Factors are year area qtr tc

                                     The GENMOD Procedure

                                      Model Information

                                Data Set              WORK.A2
                                Distribution           Normal
                                Link Function        Identity
                                Dependent Variable    lncpuedf


                           Number of Observations Read       44884
                           Number of Observations Used       44884


                                   Class Level Information

           Class      Levels    Values

           YEAR           18    1995 1996 1997 1998 1999 2000 2001 2002 2003 2004
                                2005 2006 2007 2008 2009 2010 2011 9999
           AREA            7    511 512 513 514 522 525 999
           qtr             4    1 2 4 99
           tc              2    2 99


                            Criteria For Assessing Goodness Of Fit

               Criterion                     DF           Value        Value/DF

               Deviance                    45E3     145467.0081          3.2430
               Scaled Deviance             45E3      44884.0000          1.0006
               Pearson Chi-Square          45E3     145467.0081          3.2430
               Scaled Pearson X2           45E3      44884.0000          1.0006
               Log Likelihood                       -90076.4652
               Full Log Likelihood                  -90076.4652
               AIC (smaller is better)              180210.9304
               AICC (smaller is better)             180210.9691
               BIC (smaller is better)              180463.5736


         Algorithm converged.


                        Analysis Of Maximum Likelihood Parameter Estimates

                                             Standard     Wald 95% Confidence          Wald
 Parameter           DF    Estimate        Error           Limits             Chi-Square    Pr > ChiSq

 Intercept            1      0.4827       0.0698      0.3459      0.6194          47.86        <.0001
 YEAR        1995     1     -0.3698       0.0583     -0.4840     -0.2556          40.26        <.0001
 YEAR        1996     1     -0.3584       0.0611     -0.4783     -0.2386          34.37        <.0001
 YEAR        1997     1     -0.3029       0.0617     -0.4238     -0.1820          24.11        <.0001
 YEAR        1998     1     -0.4484       0.0640     -0.5738     -0.3229          49.09        <.0001
 YEAR        1999     1     -0.1309       0.0628     -0.2540     -0.0078           4.34        0.0372
 YEAR        2000     1     -0.3017       0.0596     -0.4186     -0.1848          25.60        <.0001
```

Table B48 Cont.

whhake glm log(cpue) using df 13:07 Friday, January 25, 2013 2
Factors are year area qtr tc

The GENMOD Procedure

Analysis Of Maximum Likelihood Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Wald Chi-Square	Pr > ChiSq
YEAR	2001	1	-0.4643	0.0595	-0.5809	-0.3477	60.91	<.0001
YEAR	2002	1	-0.2926	0.0600	-0.4102	-0.1751	23.81	<.0001
YEAR	2003	1	0.3013	0.0583	0.1871	0.4155	26.73	<.0001
YEAR	2004	1	0.2172	0.0603	0.0990	0.3354	12.98	0.0003
YEAR	2005	1	-0.2902	0.0600	-0.4078	-0.1725	23.35	<.0001
YEAR	2006	1	-0.4876	0.0611	-0.6074	-0.3679	63.68	<.0001
YEAR	2007	1	-0.4147	0.0591	-0.5305	-0.2990	49.31	<.0001
YEAR	2008	1	-0.2561	0.0578	-0.3693	-0.1429	19.65	<.0001
YEAR	2009	1	-0.1863	0.0579	-0.2999	-0.0728	10.35	0.0013
YEAR	2010	1	-0.0664	0.0620	-0.1878	0.0551	1.15	0.2841
YEAR	2011	1	0.5362	0.0577	0.4230	0.6494	86.22	<.0001
YEAR	9999	0	0.0000	0.0000	0.0000	0.0000	.	.
AREA	511	1	-1.1472	0.1147	-1.3720	-0.9224	100.03	<.0001
AREA	512	1	-1.2005	0.1023	-1.4011	-1.0000	137.68	<.0001
AREA	513	1	-2.9205	0.0371	-2.9931	-2.8478	6204.93	<.0001
AREA	514	1	-3.6273	0.0373	-3.7004	-3.5542	9461.06	<.0001
AREA	522	1	-3.2538	0.0382	-3.3286	-3.1789	7257.86	<.0001
AREA	525	1	-3.3579	0.2178	-3.7848	-2.9309	237.64	<.0001
AREA	999	0	0.0000	0.0000	0.0000	0.0000	.	.
qtr	1	1	-0.5281	0.0487	-0.6236	-0.4327	117.57	<.0001
qtr	2	1	-0.5335	0.0264	-0.5853	-0.4818	408.81	<.0001
qtr	4	1	-0.2776	0.0204	-0.3176	-0.2375	184.72	<.0001
qtr	99	0	0.0000	0.0000	0.0000	0.0000	.	.
tc	2	1	-0.9883	0.0474	-1.0813	-0.8954	434.36	<.0001
tc	99	0	0.0000	0.0000	0.0000	0.0000	.	.
Scale		1	1.8003	0.0060	1.7885	1.8121		

NOTE: The scale parameter was estimated by maximum likelihood.

Table B49. White hake landings (mt) used in the GLM for directed trips, total landings, nominal and standardized effort, and landings per day fished (LPUE) for the sink gill net fleet.

year	Landings in GLM	Total SGN Landings	Nominal Effort	Nominal LPUE	Standardized Effort	Standardized LPUE
1994	277	1066	7319	0.146	304	3.503
1995	577	1109	7582	0.146	286	3.879
1996	476	916	6234	0.147	321	2.855
1997	329	538	4601	0.117	228	2.359
1998	389	731	4195	0.174	190	3.850
1999	622	983	4680	0.210	209	4.694
2000	683	1066	5696	0.187	248	4.293
2001	707	1003	6500	0.154	333	3.012
2002	571	823	5710	0.144	196	4.208
2003	973	1417	6344	0.223	179	7.926
2004	617	958	5877	0.163	163	5.881
2005	303	573	6670	0.086	178	3.217
2006	187	318	4990	0.064	149	2.127
2007	272	393	5399	0.073	110	3.562
2008	276	400	5332	0.075	124	3.218
2009	277	440	5786	0.076	132	3.340
2010	278	403	3564	0.113	87	4.659
2011	538	582	3932	0.148	100	5.845

Table B50. AIC values for models fit to **white hake** length data.

Model	Model	-LL	# parameters	AIC_c	$\Delta (AIC_c)$	AIC_c Weights
1	All stations, constant (no length effect)	1586.674	2	3177.354	12.415	0.0017
2	Survey, S-S, constant	1584.259	4	3176.541	11.6022	0.0026
3	S,F,S-S, constant model	1576.446	6	3164.939	0	0.856
4	All stations, logistic model (free slope)	1579.413	5	3168.859	3.9203	0.1206
5	All stations, logistic model (declining slope)	1581.257	5	3172.547	7.6079	0.0191

Table B51. Stratified mean catch per tow in numbers and weight (kg) for white hake from NEFSC offshore spring research vessel bottom trawl surveys (strata 21-30,36-40), 1968-2012.

		Number				Biomass			Individual			Length					Number of
Year	Mean	L80%CI	U80%CI	CV	Mean	L80%CI	U80%CI	CV	Mean Wt	Min	5%	50%	Mean	95%	Max	Number of Tows	Nonzero Tows	Area	Temp	Depth	Average Day
1968	1.631	1.144	2.117	21.2	1.937	1.229	2.645	27.0	1.188	10	23	43	45.2	83	118	74	29	22745	5.0	172.1	102
1969	4.018	2.723	5.313	23.6	5.848	4.325	7.372	19.6	1.455	17	26	41	47.7	89	127	74	37	22745	5.5	174.9	93
1970	6.651	4.323	8.980	21.1	13.813	3.659	23.967	39.8	2.077	22	27	50	53.3	78	114	75	42	22745	6.5	181.1	86
1971	3.683	2.780	4.586	18.5	5.930	4.291	7.568	21.0	1.610	17	27	50	52.1	82	121	81	40	22745	6.4	173.2	99
1972	11.553	8.804	14.301	17.8	14.583	9.232	19.934	27.0	1.262	18	28	39	47.6	77	112	80	54	22745	6.4	177.6	102
1973	10.544	7.157	13.931	24.1	14.016	10.127	17.904	20.9	1.329	18	28	46	50.0	77	120	71	49	22745	6.6	175.9	118
1974	8.809	6.865	10.752	16.5	16.068	12.150	19.985	18.2	1.824	13	31	58	56.6	80	126	68	47	22745	6.6	177.6	116
1975	9.313	6.802	11.824	19.8	11.591	8.935	14.247	17.1	1.245	9	14	42	45.2	76	115	75	43	22015	6.7	169.0	120
1976	11.202	8.790	13.615	16.2	19.616	13.416	25.817	23.4	1.751	10	27	48	53.4	82	122	87	64	22745	7.1	179.9	106
1977	6.961	5.130	8.792	19.6	12.008	8.682	15.334	20.6	1.725	22	29	52	55.2	83	128	91	51	22745	5.6	169.0	126
1978	3.367	2.521	4.214	19.2	6.254	4.422	8.086	22.1	1.857	20	26	45	51.2	82	131	94	42	22745	5.7	171.4	127
1979	5.856	4.414	7.298	18.7	5.693	3.776	7.609	25.1	0.972	16	25	40	43.4	74	113	117	61	22745	5.4	174.1	115
1980	11.896	9.440	14.352	15.5	15.607	12.113	19.101	16.7	1.312	10	28	45	49.5	76	123	71	51	22745	5.5	174.1	118
1981	17.888	13.308	22.467	15.4	21.612	5.453	37.772	30.1	1.208	11	25	42	46.8	78	124	74	57	22745	5.5	177.3	131
1982	6.635	4.399	8.871	24.3	10.031	6.756	13.306	23.9	1.512	19	29	46	51.4	77	122	77	45	22745	5.8	178.7	120
1983	3.226	2.525	3.926	16.5	3.232	2.511	3.953	16.9	1.002	15	24	41	43.8	73	102	75	48	22745	5.9	175.4	112
1984	2.714	2.004	3.424	19.7	4.605	2.823	6.386	26.8	1.697	15	30	50	54.0	77	118	73	34	22745	6.2	179.1	104
1985	4.707	3.629	5.785	16.9	6.056	4.273	7.839	22.1	1.287	26	30	47	49.4	73	117	66	33	22745	6.1	179.7	96
1986	8.821	7.406	10.236	12.1	6.083	4.868	7.297	15.1	0.690	14	25	35	40.2	69	96	75	54	22745	7.2	179.2	107
1987	7.695	6.297	9.092	13.7	7.079	5.663	8.494	15.2	0.920	12	27	42	45.4	68	128	70	46	22745	5.7	180.3	112
1988	4.711	3.999	5.423	11.3	4.103	3.434	4.773	12.4	0.871	20	24	38	42.9	70	95	76	43	22745	6.5	176.2	100
1989	3.532	2.363	4.702	24.8	3.440	1.934	4.946	32.6	0.974	16	28	39	44.7	74	92	71	36	22745	5.7	178.4	95
1990	12.323	3.894	20.753	48.4	20.805	-1.111	42.720	74.5	1.688	22	26	55	53.8	77	119	75	45	22745	4.1	181.3	96
1991	9.015	7.400	10.630	13.4	6.813	5.158	8.468	17.8	0.756	9	24	39	42.1	68	131	72	48	22745	6.1	185.5	97
1992	7.872	5.958	9.787	18.4	7.485	4.391	10.579	26.3	0.951	22	27	44	45.2	66	105	74	46	22745	6.4	177.7	100
1993	8.124	6.341	9.908	16.3	7.584	5.712	9.457	18.0	0.934	17	25	45	46.6	68	85	73	42	22745	5.4	173.8	109
1994	4.513	3.554	5.473	15.8	3.415	1.983	4.847	25.3	0.757	18	25	38	41.2	65	96	74	49	22745	6.6	176.1	107
1995	4.185	3.306	5.064	15.8	4.283	3.168	5.398	19.5	1.023	14	27	42	45.5	73	100	74	39	22745	6.6	177.1	109
1996	3.009	2.485	3.532	12.9	3.426	2.732	4.119	14.3	1.139	12	19	45	47.0	69	104	70	42	22745	6.7	175.8	113
1997	1.875	1.439	2.311	17.6	0.893	0.668	1.117	18.7	0.476	18	24	38	38.6	57	67	75	29	22745	6.7	169.2	99
1998	2.233	1.747	2.719	16.3	1.168	0.873	1.464	19.0	0.523	18	25	34	38.7	61	74	101	49	22745	6.1	177.4	101
1999	3.344	2.210	4.477	25.4	3.095	1.533	4.658	37.0	0.926	10	26	41	45.1	69	89	75	39	22745	6.2	179.5	105
2000	5.366	4.359	6.373	14.0	3.692	2.906	4.477	15.9	0.688	16	25	37	41.4	65	75	75	47	22745	6.8	171.8	113
2001	4.912	4.063	5.760	13.1	5.210	4.160	6.260	15.2	1.061	12	28	46	48.4	69	108	75	39	22745	6.5	185.9	109
2002	5.342	3.794	6.890	21.1	6.605	4.137	9.073	25.3	1.236	17	25	52	49.6	70	105	77	42	22745	6.9	176.6	106
2003	5.337	4.368	6.306	13.4	6.203	4.902	7.503	15.4	1.162	16	27	43	47.9	75	92	74	37	22745	5.9	183.7	107
2004	4.747	3.303	6.191	22.2	5.477	2.449	8.505	39.2	1.154	19	24	43	47.0	76	99	73	35	22745	5.2	181.3	102
2005	3.752	2.975	4.529	15.7	5.763	3.767	7.760	26.0	1.536	15	22	45	50.0	92	106	73	34	22745	5.8	177.1	104
2006	2.504	2.114	2.894	11.7	1.586	1.153	2.019	20.4	0.633	17	21	32	37.8	70	97	82	49	22745	7.0	174.4	99
2007	2.656	1.992	3.320	17.0	3.099	1.829	4.369	29.5	1.167	19	27	44	48.0	78	110	72	34	22745	5.9	172.3	105
2008	6.877	4.406	9.348	23.6	4.246	2.219	6.274	32.3	0.618	12	23	39	40.1	61	84	72	48	22745	5.6	177.6	111
2009	6.759	5.195	8.322	18.8	4.767	3.285	6.249	25.0	0.705	13	21	38	40.8	63	89	95	69	22745	5.9	176.0	112
2010	5.411	4.631	6.191	13.1	5.652	4.311	6.992	19.6	1.044	12	25	43	45.8	69	91	87	70	22745	6.8	175.4	109
2011	5.095	4.360	5.831	13.3	5.521	4.597	6.445	16.0	1.084	8	28	44	47.4	72	93	77	61	22745	7.7	177.2	118
2012	4.204	3.677	4.731	12.2	4.209	3.468	4.950	16.5	1.001	20	29	41	45.4	73	96	95	66	22745	7.6	175.3	111

Table 52. Stratified mean catch per tow in numbers and weight (kg) for white hake from NEFSC offshore autumn research vessel bottom trawl surveys (strata 21-30,36-40), 1963-2012.

																	Number of				
		Number				Biomass			Individual			Length				Number	Nonzero				
Year	Mean	L95%CI	U95%CI	CV	Mean	L95%CI	U95%CI	CV	Mean Wt	Min	5%	50%	Mean	95%	Max	of Tows	Tows	Area	Temp	Depth	Average Day
1963	5.468	4.435	6.501	13.0	7.523	5.601	9.446	19.0	1.376	13	23	45	48.0	74	121	81	48	22745	7.1	166.5	325
1964	1.761	1.327	2.195	18.5	4.089	2.903	5.276	22.1	2.322	24	28	51	56.3	104	123	72	31	22745	5.8	172.3	320
1965	4.160	3.037	5.284	19.8	6.609	5.109	8.110	16.7	1.589	15	27	46	50.8	80	125	74	51	22745	6.1	171.3	286
1966	7.563	6.154	8.973	13.7	8.405	6.892	9.917	13.6	1.111	18	26	40	45.1	72	121	68	53	22745	5.7	163.0	291
1967	4.023	3.175	4.870	15.9	4.122	3.079	5.166	18.8	1.025	20	22	40	43.6	71	117	72	46	22745	6.0	175.1	322
1968	4.397	2.902	5.891	22.3	4.886	3.105	6.667	25.1	1.111	11	23	42	45.3	71	120	73	48	22745	6.9	178.6	318
1969	10.147	8.433	11.861	12.5	13.404	10.613	16.195	15.2	1.321	14	23	43	47.3	74	112	74	54	22745	7.3	178.2	318
1970	8.848	7.397	10.300	12.5	14.174	11.178	17.169	16.0	1.602	21	26	50	51.6	77	119	77	59	22745	7.6	168.9	314
1971	11.196	7.637	14.755	21.7	13.468	11.355	15.580	11.6	1.203	12	25	40	44.5	74	130	79	65	22745	8.3	174.9	308
1972	14.029	7.994	20.065	28.4	14.556	10.648	18.464	18.4	1.038	9	24	42	45.4	72	116	78	62	22745	8.2	166.1	311
1973	9.863	7.684	12.041	15.9	14.800	11.362	18.238	17.2	1.501	8	26	49	51.8	81	119	78	62	22745	8.1	175.2	310
1974	5.400	4.463	6.337	13.1	12.121	9.748	14.495	14.8	2.245	19	27	54	56.6	85	130	80	59	22745	8.3	179.2	297
1975	5.146	4.227	6.066	13.1	7.826	6.385	9.267	13.5	1.521	15	25	45	50.0	82	116	89	61	22745	7.9	167.5	299
1976	6.742	5.167	8.316	17.2	11.695	9.219	14.172	15.9	1.735	8	33	51	54.5	81	123	75	61	22745	8.6	172.9	314
1977	10.575	9.038	12.113	11.0	13.872	11.839	15.905	11.2	1.312	10	21	43	47.0	79	123	112	87	22745	7.9	173.7	323
1978	8.343	7.107	9.578	11.2	13.323	11.097	15.549	12.3	1.597	12	25	45	50.0	82	131	176	133	22745	7.2	172.8	301
1979	5.561	4.685	6.436	12.0	10.568	8.269	12.868	16.1	1.901	22	33	47	53.5	83	127	193	137	22745	7.6	173.2	310
1980	12.001	9.302	14.700	17.1	18.410	12.081	24.739	25.3	1.534	4	8	49	48.8	78	118	81	66	22745	7.4	170.2	307
1981	8.428	6.734	10.123	12.3	11.870	9.987	13.753	11.7	1.408	22	32	44	50.5	79	96	74	51	22745	7.1	172.2	304
1982	1.876	1.427	2.325	17.8	1.954	1.392	2.516	21.8	1.042	12	24	43	45.9	75	93	79	41	22745	7.9	171.1	303
1983	8.991	7.369	10.613	13.3	11.513	9.560	13.466	12.9	1.281	22	29	43	48.6	71	117	71	53	22745	8.0	172.8	303
1984	5.173	4.483	5.862	10.1	8.152	6.969	9.335	10.8	1.576	22	26	49	52.3	76	123	72	57	22745	8.1	182.9	298
1985	9.460	7.489	11.431	15.7	9.795	7.280	12.309	19.3	1.035	9	21	39	42.4	75	128	73	56	22745	8.3	171.7	306
1986	15.181	12.743	17.618	12.0	11.450	9.951	12.949	9.9	0.754	10	17	40	41.2	66	108	75	66	22745	8.4	174.3	299
1987	7.852	6.815	8.888	10.1	9.801	7.644	11.957	16.2	1.248	17	24	46	48.7	76	113	73	54	22745	7.6	176.0	293
1988	8.540	7.219	9.861	11.7	10.430	8.076	12.785	16.7	1.221	19	27	41	46.1	69	136	75	61	22745	7.1	174.9	293
1989	12.538	9.577	15.499	17.7	9.255	7.867	10.642	11.4	0.738	9	19	39	39.8	68	90	73	60	22745	6.9	179.0	296
1990	13.861	11.307	16.415	13.8	10.895	7.966	13.823	19.6	0.786	5	12	39	41.2	64	83	75	61	22745	5.8	174.4	288
1991	13.672	11.047	16.298	14.6	12.541	9.314	15.767	18.8	0.917	16	24	41	44.5	68	94	75	66	22745	7.8	170.3	286
1992	10.746	9.547	11.946	8.5	11.843	10.178	13.509	10.5	1.102	16	30	46	47.7	67	115	73	59	22745	7.3	183.1	292
1993	10.504	8.721	12.287	12.0	12.039	9.910	14.168	12.9	1.146	14	24	47	47.8	68	86	72	63	22745	7.6	180.7	285
1994	7.381	6.334	8.427	10.6	5.924	5.114	6.735	10.4	0.803	3	20	40	41.3	66	88	73	62	22745	8.7	183.0	289
1995	10.072	8.751	11.393	9.9	8.439	7.106	9.772	11.9	0.838	3	4	40	40.1	65	126	79	62	22745	7.9	174.5	285
1996	4.684	4.046	5.322	10.0	6.651	5.407	7.896	13.8	1.420	10	24	51	51.2	70	97	74	50	22745	8.0	173.8	290
1997	5.031	4.179	5.884	12.7	4.896	3.923	5.868	14.8	0.973	18	22	37	41.3	70	118	76	56	22745	7.9	174.9	290
1998	4.958	4.339	5.577	9.6	4.737	4.000	5.475	11.8	0.956	12	25	41	44.3	67	97	90	68	22745	6.9	174.4	299
1999	6.154	4.507	7.800	20.0	3.648	2.939	4.357	14.8	0.593	11	17	30	36.0	62	92	93	65	22745	8.4	169.6	303
2000	7.569	6.459	8.678	11.2	6.800	5.752	7.847	11.8	0.898	5	24	40	43.7	66	110	73	52	22745	8.2	169.5	284
2001	5.704	4.851	6.557	11.3	7.852	6.764	8.939	10.5	1.377	19	34	51	52.4	69	97	77	51	22745	7.7	171.7	285
2002	6.861	4.203	9.519	25.3	6.720	5.273	8.167	16.3	0.979	18	22	37	42.2	71	110	72	49	22745	8.8	174.5	290
2003	4.031	3.226	4.835	14.7	4.531	3.507	5.556	17.1	1.124	20	22	42	44.8	78	87	74	43	22745	7.6	179.6	293
2004	3.550	2.915	4.184	13.1	3.695	2.947	4.442	15.4	1.041	17	24	39	44.7	72	116	71	52	22745	6.7	171.5	292
2005	3.585	2.960	4.211	13.3	3.837	3.039	4.634	15.8	1.070	18	21	41	45.1	73	114	73	42	22745	8.0	173.0	296
2006	4.751	4.127	5.375	9.9	4.272	3.646	4.897	11.1	0.899	9	25	38	43.0	71	111	80	58	22745	8.3	167.2	286
2007	6.636	5.537	7.735	12.5	7.222	5.801	8.643	15.0	1.088	10	25	46	47.6	64	118	76	58	22745	7.2	177.2	292
2008	7.345	6.024	8.666	13.5	7.056	5.470	8.642	16.6	0.961	4	11	42	43.3	71	92	76	56	22745	4.9	175.7	295
2009	5.327	4.654	6.000	12.3	4.760	4.034	5.485	15.2	0.893	13	22	41	43.1	65	98	73	65	22745	8.1	177.3	312
2010	7.951	6.764	9.139	13.5	7.854	6.390	9.317	17.0	0.988	12	24	42	44.8	67	96	68	62	22745	8.9	174.2	314
2011	6.945	5.885	8.006	13.6	9.020	7.375	10.666	16.8	1.299	8	25	45	48.6	71	101	66	58	22745	8.6	184.2	305
2012	5.380	4.846	5.913	10.8	7.739	6.934	8.543	12.7	1.344	19	25	46	49.2	74	111	85	70	22745	na	181.1	295

Table B53. Stratified mean catch per tow in numbers and weight (kg) for white hake from ASMFC shrimp surveys from 1985-2012. White hake were not counted or measured on every tow from 1985-1989.

																		Number of				
		Number				Biomass			Individual			Length				Number	Nonzero				
Year	Mean	L80%CI	U80%CI	CV	Mean	L80%CI	U80%CI	CV	Mean Wt	Min	5%	50%	Mean	95%	Max	of Tows	Tows	Area	Temp	Depth	Average Day
1985					11.120	6.634	15.603	28.6								44	37	6147	4.0	187.8	221
1986					12.520	9.328	15.716	17.8								40	38	6147	6.3	184.3	214
1987					20.070	16.920	23.215	11.2								41	40	6147	6.0	151.5	221
1988					14.100	11.862	16.340	11.5								41	41	6147	6.5	200.7	222
1989					7.981	6.576	9.386	13.4								43	40	6147	5.6	183.7	217
1990	16.210	11.240	21.174	22.6	9.641	6.857	12.425	21.5	0.595	21	27	34	38.2	54	84	43	37	6147	3.6	192.0	216
1991	17.850	15.004	20.704	12.1	10.460	8.508	12.416	13.9	0.586	15	28	37	39.7	56	69	43	43	6147	6.1	145.3	214
1992	15.550	13.638	17.464	9.4	12.510	11.023	14.000	9.0	0.805	12	29	42	43.3	58	116	45	45	6147	6.3	191.7	220
1993	8.593	7.257	9.929	11.8	9.146	7.898	10.393	10.2	1.064	14	29	44	46.7	67	119	46	42	6147	5.8	193.8	219
1994	8.234	6.155	10.314	18.2	6.462	5.409	7.516	12.2	0.785	17	26	38	41.0	66	95	43	40	6147	6.8	177.2	218
1995	14.030	11.384	16.682	13.6	10.390	8.745	12.043	11.5	0.741	12	31	40	42.9	63	88	35	33	6147	6.6	178.3	218
1996	8.132	5.851	10.414	19.7	6.676	4.428	8.924	23.8	0.821	9	27	42	43.3	61	72	32	30	6147	7.1	172.8	216
1997	4.322	3.357	5.286	16.6	3.252	2.451	4.052	18.3	0.752	10	30	38	41.8	65	81	40	33	6147	6.8	188.0	213
1998	6.027	4.864	7.191	14.5	4.418	3.540	5.296	14.6	0.733	3	29	38	41.4	60	71	35	31	6147	6.3	175.5	214
1999	8.321	5.573	11.069	23.8	7.162	5.256	9.067	19.9	0.861	23	28	40	43.2	65	93	42	37	6147	6.1	180.6	212
2000	16.570	10.602	22.532	26.8	8.854	6.882	10.825	16.8	0.534	16	25	35	37.5	55	88	35	32	6147	6.7	178.8	210
2001	9.636	6.809	12.463	20.8	10.560	6.966	14.152	24.0	1.096	28	34	47	48.5	61	104	36	31	6147	6.5	176.8	209
2002	10.670	8.086	13.255	17.9	14.240	9.601	18.870	18.1	1.334	25	30	49	50.4	71	83	38	37	6147	7.1	178.1	208
2003	11.200	8.865	13.525	15.7	10.290	7.883	12.699	17.0	0.919	15	28	36	43.2	74	90	37	35	6147	5.6	167.5	213
2004	14.780	5.602	23.951	44.7	9.781	7.179	12.383	19.8	0.662	21	25	32	38.7	66	93	35	29	6147	4.7	187.7	214
2005	8.705	7.540	9.871	10.2	7.618	6.235	9.002	13.6	0.875	23	26	39	42.8	69	99	46	43	6147	4.9		212
2006	10.390	7.802	12.969	18.4	10.290	8.471	12.112	13.2	0.991	16	24	36	41.3	69	106	29	29	6147	7.1		213
2007	10.300	8.258	12.349	15.1	8.947	7.059	10.836	15.8	0.868	17	27	38	42.5	67	100	43	39	6147	5.9		213
2008	9.291	6.593	11.989	21.9	7.353	5.768	8.937	16.2	0.791	19	26	37	41.7	65	112	37	36	6147	5.9	176.1	216
2009	10.900	7.763	14.034	21.1	11.570	7.254	15.895	27.6	1.062	10	25	42	45.4	73	117	49	49	6147	6.0	168.7	205
2010	13.050	10.345	15.760	15.4	10.430	8.386	12.475	14.5	0.799	19	29	40	44.0	64	80	49	48	6147	7.4	172.8	203
2011	13.610	11.156	16.066	13.6	12.790	10.642	14.938	12.9	0.940	25	29	39	44.6	72	96	47	46	6147		169.2	203
2012	8.801	7.263	10.340	13.3	9.626	8.215	11.037	11.2	1.094	17	30	42	46.8	69	91	49	48	6147		170.7	217

Table B54. Abundance and biomass indices of white hake from the MDMF Spring Survey, Regions 1-5.

		Number				Biomass			Individual			
Year	Mean	L95%CI	U95%CI	CV	Mean	L95%CI	U95%CI	CV	Mean Wt	Temp	Depth	Average Day
1978	2.255	-1.188	5.698	49.3	0.243	-0.042	0.528	42.5	0.108	10.5	19.4	148
1979	2.400	0.576	4.225	31.8	0.367	-0.243	0.978	61.4	0.153	9.4	21.3	130
1980	2.129	-0.371	4.629	41.7	0.082	0.021	0.143	30.4	0.038	9.5	21.4	135
1981	4.285	2.361	6.210	21.5	0.242	0.081	0.403	29.5	0.057	8.6	21.4	133
1982	0.375	0.132	0.619	31.3	0.029	-0.002	0.061	44.1	0.078	8.1	19.6	132
1983	1.087	0.344	1.831	31.3	0.080	0.020	0.140	33.1	0.073	9.0	21.6	136
1984	1.068	-1.215	3.350	75.3	0.048	-0.050	0.147	70.2	0.045	8.6	22.2	135
1985	1.633	-0.543	3.808	49.7	0.025	-0.008	0.058	38.8	0.016	9.2	22.3	134
1986	2.612	1.310	3.914	21.3	0.614	0.236	0.993	24.4	0.235	8.6	21.9	133
1987	0.242	0.044	0.439	34.4	0.040	-0.005	0.086	40.6	0.167	8.8	22.5	131
1988	0.426	0.184	0.669	25.4	0.038	0.009	0.067	29.8	0.090	8.5	22.0	138
1989	0.620	0.242	0.998	24.4	0.110	0.046	0.174	22.4	0.178	6.7	21.4	136
1990	1.082	0.672	1.492	16.7	0.202	0.117	0.287	17.6	0.187	8.2	22.1	135
1991	0.378	-0.050	0.806	43.5	0.043	-0.016	0.102	50.9	0.114	10.4	21.4	134
1992	0.630	-0.471	1.731	65.3	0.019	-0.007	0.045	52.4	0.031	8.4	21.6	134
1993	0.350	-0.240	0.940	63.8	0.004	-0.014	0.023	100.0	0.012	8.7	22.1	132
1994	0.438	0.120	0.756	31.9	0.014	-0.002	0.029	50.6	0.031	8.3	22.2	137
1995	0.562	0.031	1.092	38.8	0.028	-0.127	0.183	63.9	0.050	8.7	22.3	136
1996	1.080	-0.848	3.009	65.4	0.001	-0.002	0.004	100.0	0.001	8.3	22.2	135
1997	0.552	0.191	0.914	30.0	0.029	0.013	0.045	22.7	0.052	8.3	22.3	133
1998	0.369	0.155	0.582	27.2	0.009	-0.001	0.019	42.6	0.024	8.5	22.4	133
1999	0.199	0.051	0.348	33.4	0.007	-0.002	0.015	50.5	0.033	10.3	22.1	138
2000	0.698	0.015	1.381	37.0	0.021	0.010	0.033	21.3	0.031	10.0	22.1	137
2001	0.366	0.022	0.710	39.6	0.003	-0.003	0.009	73.1	0.009	9.2	22.7	135
2002	1.602	-6.734	9.938	64.9	0.020	-0.081	0.121	42.4	0.013	9.5	21.8	134
2003	0.718	0.051	1.385	40.6	0.001	-0.001	0.002	100.0	0.001	8.3	22.7	133
2004	0.090	0.016	0.164	36.7	0.004	0.000	0.009	42.0	0.049	8.4	21.9	132
2005	0.066	-0.041	0.173	64.2	0.003	-0.011	0.016	76.6	0.039	8.1	22.9	139
2006	0.740	-1.575	3.055	47.0	0.088	-0.159	0.334	31.6	0.119	9.5	22.3	137
2007	0.382	-3.129	3.893	75.6	0.063	-0.645	0.771	89.7	0.165	8.8	22.3	136
2008	0.134	-0.422	0.690	40.7	0.014	-0.081	0.109	53.8	0.103	8.2	22.5	134
2009	0.203	-0.074	0.479	48.2	0.015	-0.006	0.036	50.8	0.074	8.9	21.9	132
2010	0.266	-0.156	0.689	42.1	0.031	-0.028	0.090	45.4	0.116	9.2	22.2	130
2011	0.031	-0.124	0.185	76.0	0.004	-0.023	0.031	80.2	0.125	8.9	21.7	131
2012	0.105	-1.068	1.278	91.8	0.034	-0.377	0.444	96.9	0.320	10.9	22.0	135

Table B55. Abundance and biomass indices of white hake from the MDMF Autum Survey, Regions 1-5.

		Number				Biomass			Individual			
Year	Mean	L95%CI	U95%CI	CV	Mean	L95%CI	U95%CI	CV	Mean Wt	Temp	Depth	Average D
1978	13.610	7.510	19.710	16.6	0.840	0.468	1.212	17.5	0.062	13.0	20.9	261
1979	5.720	3.329	8.110	19.0	0.613	0.364	0.862	18.8	0.107	13.0	21.0	265
1980	13.590	10.312	16.868	11.4	0.959	0.704	1.213	12.6	0.071	14.7	21.2	262
1981	9.217	2.911	15.524	27.2	0.863	0.408	1.317	21.7	0.094	15.6	21.2	268
1982	5.202	1.388	9.016	28.0	0.579	0.243	0.915	25.9	0.111	13.7	21.4	260
1983	1.465	0.845	2.084	19.2	0.299	0.145	0.453	22.2	0.204	13.6	21.2	258
1984	0.638	-1.261	2.536	47.4	0.056	-0.093	0.206	45.7	0.089	13.8	21.8	262
1985	11.747	-13.249	36.743	77.0	0.184	0.068	0.301	27.8	0.016	15.6	22.1	253
1986	1.254	0.792	1.716	17.6	0.211	0.070	0.352	24.5	0.168	14.0	22.1	258
1987	3.705	-5.836	13.246	65.0	0.073	-0.046	0.192	55.3	0.020	12.3	22.5	260
1988	1.546	0.260	2.833	22.2	0.189	0.099	0.279	20.1	0.122	12.5	22.0	259
1989	4.470	0.027	8.913	37.9	0.238	0.096	0.380	18.8	0.053	13.9	21.8	255
1990	3.153	1.411	4.895	24.7	0.514	0.196	0.831	26.7	0.163	15.9	21.8	254
1991	1.528	0.503	2.553	26.7	0.249	0.081	0.416	28.0	0.163	16.1	21.9	255
1992	4.391	-21.570	30.353	61.2	0.227	-1.404	1.857	64.9	0.052	13.7	22.0	261
1993	5.036	-5.090	15.162	64.5	0.327	-0.334	0.987	64.9	0.065	13.7	22.3	258
1994	3.483	0.667	6.298	22.9	0.324	0.197	0.451	16.9	0.093	15.9	22.2	257
1995	15.219	-43.272	73.710	89.4	0.089	0.033	0.145	27.9	0.006	10.4	22.0	256
1996	4.122	0.957	7.287	31.3	0.149	0.055	0.242	24.9	0.036	15.2	22.4	255
1997	1.036	0.469	1.603	12.9	0.090	0.007	0.174	27.1	0.087	15.3	21.6	259
1998	1.195	0.215	2.176	30.7	0.045	0.003	0.088	34.3	0.038	13.5	22.2	261
1999	6.058	-8.898	21.014	38.5	0.192	0.080	0.304	25.6	0.032	15.2	22.3	258
2000	0.794	0.081	1.508	36.3	0.060	0.013	0.108	31.4	0.076	15.9	21.9	257
2001	1.698	-2.703	6.100	61.3	0.073	-0.008	0.154	34.2	0.043	14.2	22.4	255
2002	0.555	0.126	0.985	29.8	0.097	-0.631	0.825	66.8	0.174	16.4	22.0	254
2003	0.835	0.534	1.136	17.0	0.017	0.008	0.027	26.4	0.021	14.4	22.3	253
2004	1.217	-0.997	3.431	70.2	0.023	-0.004	0.050	43.5	0.019	13.0	22.3	265
2005	0.893	-0.554	2.340	59.9	0.067	0.005	0.129	34.7	0.075	14.5	23.1	256
2006	0.524	0.187	0.862	28.0	0.118	-0.031	0.266	45.3	0.224	15.2	22.2	259
2007	0.536	-0.055	1.128	39.1	0.064	-0.330	0.458	56.1	0.120	14.4	22.1	254
2008	0.198	0.015	0.381	32.6	0.061	-0.459	0.580	70.7	0.306	15.8	22.2	255
2009	4.440	2.202	6.678	22.5	0.275	0.149	0.401	20.8	0.062	15.9	21.8	259
2010	0.907	0.576	1.237	15.2	0.081	0.018	0.144	27.1	0.089	15.1	21.5	258
2011	5.898	2.004	9.791	26.6	0.360	0.111	0.610	27.1	0.061	15.6	21.8	257
2012	0.097	-0.037	0.230	51.2	0.019	-0.114	0.153	65.3	0.200	15.2	21.3	257

Table B56. Abundance and biomass indices of white hake from the ME/NH survey.

SPRING					AUTUMN				
	Number		Weight			Number		Weight	
	Mean	SE	Mean	SE		Mean	SE	Mean	SE
					2000	13.03	1.22	1.63	0.16
2001	0.65	0.15	0.04	0.01	2001	18.90	2.75	2.83	0.33
2002	2.10	0.40	0.28	0.06	2002	23.65	1.88	2.71	0.27
2003	1.94	0.47	0.36	0.11	2003	25.41	2.99	3.70	0.45
2004	2.39	0.41	0.17	0.03	2004	17.81	2.56	2.77	0.35
2005	4.23	0.77	0.62	0.13	2005	44.82	3.11	2.35	0.22
2006	6.12	0.72	0.55	0.08	2006	31.06	3.68	2.05	0.21
2007	4.11	0.91	0.48	0.17	2007	32.90	2.82	4.12	0.51
2008	6.79	0.78	0.76	0.12	2008	99.93	8.38	5.00	0.33
2009	15.38	1.34	1.16	0.14	2009	35.54	2.22	4.65	0.37
2010	2.49	0.35	0.37	0.14	2010	24.20	2.47	2.37	0.27
2011	3.85	0.51	0.44	0.06	2011	40.23	2.63	4.30	0.39
2012	3.02	0.35	0.48	0.08					

Table B57. Number of ages available for survey ALKs for all areas and for the stock area.

	Spring		Autumn		Total	
Year	Stock	Total	Stock	Total	Stock	Total
1982	228	362	189	283	417	645
1983	200	309	396	483	596	792
1984	152	224	325	450	477	674
1985	259	411	395	652	654	1063
1986	426	686	486	669	912	1355
1987	171	191	373	443	544	634
1988	233	276	399	476	632	752
1989	158	259	408	472	566	731
1990	379	436	539	717	918	1153
1991	388	499	545	861	933	1360
1992	285	360	591	789	876	1149
1993	339	380	530	686	869	1066
1994	222	282	370	582	592	864
1995	198	256	480	542	678	798
1996	178	199	229	279	407	478
1997	80	113	245	277	325	390
1998	148	184	330	359	478	543
1999	174	210	321	374	495	584
2000	248	289	353	424	601	713
2001	275	323	278	328	553	651
2002	211	249	213	256	424	505
2003	205	235			205	235
2004	64	95	134	186	198	281
2005	182	237	166	207	348	444
2006	140	160	209	253	349	413
2007	145	184	338	488	483	672
2008	226	247	348	469	574	716
2009	562	775	564	822	1126	1597
2010	598	755	779	952	1377	1707
2011	556	697	622	737	1178	1434
2012	512	616			512	616

Table B58. Stratified mean number per tow at age of white hake in the NEFSC spring bottom trawl surveys (Strata 21-30,36-40), 1968-2012. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+	0+	9+	1+	1+ Biomass
1968	**0.0000**	**0.1054**	**0.3564**	**0.6468**	**0.3118**	**0.0920**	**0.0548**	**0.0216**	**0.0182**	**0.0050**	**0.0185**	**1.6306**	**0.0235**	**1.6306**	**1.937**
1969	**0.0000**	**0.1497**	**1.0233**	**1.4013**	**0.6956**	**0.3596**	**0.1174**	**0.0864**	**0.0516**	**0.0535**	**0.0796**	**4.0181**	**0.1332**	**4.0181**	**5.848**
1970	**0.0000**	**0.1457**	**1.2249**	**1.7268**	**1.3533**	**1.2801**	**0.6096**	**0.1204**	**0.0704**	**0.0383**	**0.0817**	**6.6512**	**0.1199**	**6.6512**	**13.813**
1971	**0.0000**	**0.1133**	**0.5923**	**1.0283**	**1.0065**	**0.5378**	**0.2012**	**0.0877**	**0.0686**	**0.0051**	**0.0423**	**3.6831**	**0.0474**	**3.6831**	**5.930**
1972	**0.0000**	**0.3619**	**3.1629**	**3.6084**	**1.8274**	**1.4844**	**0.6803**	**0.1993**	**0.1177**	**0.0433**	**0.0669**	**11.5526**	**0.1102**	**11.5526**	**14.583**
1973	**0.0000**	**0.2031**	**1.4711**	**4.2293**	**2.7303**	**1.0648**	**0.4546**	**0.1574**	**0.1056**	**0.0331**	**0.0948**	**10.5441**	**0.1279**	**10.5441**	**14.016**
1974	**0.0000**	**0.1132**	**0.8389**	**2.0964**	**2.6523**	**1.9021**	**0.7792**	**0.1849**	**0.1164**	**0.0188**	**0.1063**	**8.8085**	**0.1251**	**8.8085**	**16.068**
1975	**0.0031**	**1.1411**	**1.9486**	**2.8729**	**1.4396**	**1.0646**	**0.5664**	**0.1425**	**0.0749**	**0.0090**	**0.0508**	**9.3133**	**0.0598**	**9.3102**	**11.591**
1976	**0.0000**	**0.2579**	**1.6218**	**3.5215**	**2.3277**	**1.8245**	**1.0120**	**0.2732**	**0.1561**	**0.0694**	**0.1383**	**11.2024**	**0.2077**	**11.2024**	**19.616**
1977	**0.0000**	**0.0985**	**0.7411**	**1.9635**	**2.1551**	**1.0247**	**0.5553**	**0.1575**	**0.0746**	**0.0778**	**0.1129**	**6.9611**	**0.1908**	**6.9611**	**12.008**
1978	**0.0000**	**0.1176**	**0.8397**	**0.8637**	**0.4970**	**0.5621**	**0.2865**	**0.0748**	**0.0396**	**0.0284**	**0.0579**	**3.3673**	**0.0863**	**3.3673**	**6.254**
1979	**0.0000**	**0.3146**	**1.8406**	**2.0077**	**0.9113**	**0.4282**	**0.2457**	**0.0602**	**0.0199**	**0.0053**	**0.0224**	**5.8557**	**0.0277**	**5.8557**	**5.693**
1980	**0.0000**	**0.4296**	**1.4291**	**4.9698**	**2.7324**	**1.2775**	**0.6862**	**0.1749**	**0.1078**	**0.0341**	**0.0542**	**11.8956**	**0.0883**	**11.8956**	**15.607**
1981	**0.0000**	**0.9692**	**5.8239**	**3.6857**	**3.6138**	**2.0111**	**1.1795**	**0.3302**	**0.1188**	**0.0253**	**0.1301**	**17.8876**	**0.1554**	**17.8876**	**21.612**
1982	0.0000	0.0488	0.8058	2.9733	0.9815	1.3927	0.2529	0.0614	0.0369	0.0004	0.0810	6.6347	0.0814	6.6347	10.031
1983	0.0000	0.0592	1.0397	1.2285	0.5433	0.1752	0.0968	0.0453	0.0378	0.0000	0.0000	3.2257	0.0000	3.2257	3.232
1984	0.0000	0.0225	0.2616	0.9816	0.6932	0.4667	0.1749	0.0723	0.0323	0.0000	0.0091	2.7141	0.0091	2.7141	4.605
1985	0.0000	0.0234	0.7502	1.9720	1.2366	0.5065	0.1234	0.0364	0.0127	0.0008	0.0452	4.7073	0.0460	4.7073	6.056
1986	0.0000	0.1082	3.3372	3.5906	1.0397	0.5213	0.2059	0.0000	0.0178	0.0000	0.0000	8.8208	0.0000	8.8208	6.083
1987	0.0000	0.0106	1.4080	4.5032	1.2079	0.3526	0.1287	0.0120	0.0265	0.0078	0.0372	7.6944	0.0449	7.6944	7.079
1988	0.0000	0.0917	1.6294	1.4568	0.8363	0.4970	0.1153	0.0410	0.0361	0.0071	0.0000	4.7108	0.0071	4.7108	4.103
1989	0.0000	0.0282	1.1084	1.4652	0.3083	0.4127	0.1848	0.0247	0.0000	0.0000	0.0000	3.5323	0.0000	3.5323	3.440
1990	0.0000	0.0698	1.8186	2.4924	4.9384	2.2076	0.3334	0.1450	0.1170	0.0671	0.1342	12.3233	0.2013	12.3233	20.805
1991	0.0411	0.1428	2.9593	2.4882	2.0192	0.9302	0.3375	0.0395	0.0170	0.0224	0.0181	9.0153	0.0405	8.9742	6.813
1992	0.0000	0.0056	0.9796	2.9314	3.4555	0.3591	0.0942	0.0376	0.0095	0.0000	0.0000	7.8724	0.0000	7.8724	7.485
1993	0.0000	0.0402	1.6917	3.3089	2.5792	0.4750	0.0258	0.0023	0.0011	0.0000	0.0000	8.1242	0.0000	8.1242	7.584
1994	0.0000	0.0388	1.4473	1.9586	0.7251	0.2224	0.0862	0.0093	0.0256	0.0000	0.0000	4.5133	0.0000	4.5133	3.415

Table B58. cont.

	0	1	2	3	4	5	6	7	8	9	10+	0+	9+	1+	1+ Biomass
1995	0.0000	0.1125	0.7682	1.9574	0.7850	0.2755	0.1753	0.0386	0.0726	0.0000	0.0000	4.1850	0.0000	4.1850	4.283
1996	0.0000	0.2299	0.4709	1.0625	0.5774	0.4682	0.0973	0.0248	0.0365	0.0409	0.0000	3.0084	0.0409	3.0084	3.426
1997	0.0000	0.0429	0.7240	0.7884	0.2650	0.0545	0.0000	0.0000	0.0000	0.0000	0.0000	1.8748	0.0000	1.8748	0.893
1998	0.0000	0.0144	1.0234	0.9315	0.1752	0.0717	0.0163	0.0000	0.0000	0.0000	0.0000	2.2325	0.0000	2.2325	1.168
1999	0.0000	0.0449	0.6021	1.5300	0.5961	0.4177	0.0898	0.0538	0.0091	0.0000	0.0000	3.3435	0.0000	3.3435	3.095
2000	0.0000	0.0885	1.5095	2.5822	0.8024	0.2790	0.0900	0.0141	0.0000	0.0000	0.0000	5.3658	0.0000	5.3658	3.692
2001	0.0000	0.0582	0.4947	2.1425	1.4781	0.4575	0.1815	0.0182	0.0361	0.0224	0.0224	4.9115	0.0447	4.9115	5.210
2002	0.0000	0.6856	1.0976	0.7497	1.7406	0.8154	0.1171	0.0684	0.0537	0.0000	0.0141	5.3423	0.0141	5.3423	6.605
2003	0.0000	0.9350	1.2200	1.0798	0.7800	0.6762	0.4278	0.1588	0.0387	0.0205	0.0000	5.3368	0.0205	5.3368	6.203
2004	0.0000	0.6236	0.5035	1.7796	1.0232	0.5166	0.1262	0.0926	0.0496	0.0311	0.0011	4.7471	0.0323	4.7471	5.477
2005	0.0450	0.5568	0.5242	0.8372	0.7524	0.3382	0.2083	0.1459	0.2331	0.0460	0.0647	3.7518	0.1107	3.7068	5.762
2006	0.0000	0.7503	0.8169	0.5001	0.1844	0.0838	0.0686	0.0440	0.0520	0.0037	0.0000	2.5039	0.0037	2.5039	1.586
2007	0.0000	0.2510	0.5549	1.0447	0.4319	0.1272	0.0432	0.0540	0.0424	0.0540	0.0531	2.6563	0.1071	2.6563	3.099
2008	0.0185	1.6148	1.7130	2.2225	1.0906	0.0639	0.0465	0.0325	0.0000	0.0605	0.0141	6.8769	0.0746	6.8583	4.246
2009	0.0000	1.0778	2.0058	1.4987	1.2658	0.6445	0.1697	0.0396	0.0254	0.0000	0.0312	6.7586	0.0312	6.7586	4.767
2010	0.0000	0.4098	1.3778	1.2609	1.2286	0.7656	0.2570	0.0531	0.0184	0.0052	0.0348	5.4112	0.0400	5.4112	5.652
2011	0.0057	0.6882	1.2204	1.4323	0.9760	0.3904	0.2724	0.0761	0.0251	0.0084	0.0000	5.0952	0.0084	5.0894	5.521
2012	0.0000	0.1836	1.3185	1.2180	0.8760	0.3688	0.1384	0.0565	0.0361	0.0080	0.0000	4.2039	0.0080	4.2039	4.209

Table B59. Proportion of the spring survey catch at age of white hake that was imputed. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+	0+	9+	1+
1968	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1969	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**8.62**	**14.45**	**13.92**	**23.63**	**1.02**	**19.73**	**1.02**
1970	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1971	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**75.55**	**0.87**	**67.40**	**0.87**
1972	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**41.57**	**54.66**	**0.47**	**49.51**	**0.47**
1973	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**28.39**	**76.61**	**0.78**	**64.11**	**0.78**
1974	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**80.52**	**0.97**	**68.41**	**0.97**
1975	**100.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**48.33**	**0.30**	**41.08**	**0.26**
1976	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**26.73**	**56.98**	**0.87**	**46.88**	**0.87**
1977	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**2.33**	**4.91**	**30.25**	**46.12**	**1.19**	**39.65**	**1.19**
1978	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**84.73**	**83.61**	**2.15**	**83.98**	**2.15**
1979	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1980	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**9.21**	**0.04**	**5.65**	**0.04**
1981	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**27.42**	**0.20**	**22.95**	**0.20**
1982	0.00	100.00	4.87	0.01	0.08	0.72	5.44	22.50	42.76	100.00	11.20	2.29	11.65	2.29
1983	0.00	0.00	0.00	0.22	3.65	9.33	4.94	16.20	9.43	0.00	0.00	1.69	0.00	1.69
1984	0.00	0.00	0.00	0.00	0.00	0.39	3.37	14.43	43.79	0.00	0.00	1.19	0.00	1.19
1985	0.00	0.00	0.00	0.00	0.27	8.46	48.60	50.15	28.35	100.00	100.00	3.70	100.00	3.70
1986	0.00	12.37	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.16
1987	0.00	100.00	5.07	0.53	6.12	15.57	34.00	100.00	100.00	100.00	100.00	4.70	100.00	4.70
1988	0.00	0.00	0.00	1.56	2.81	2.93	35.60	77.90	24.67	100.00	0.00	3.18	100.00	3.18
1989	0.00	100.00	0.24	0.61	26.07	6.15	9.12	9.37	0.00	0.00	0.00	4.66	0.00	4.66
1990	0.00	0.00	0.00	0.00	0.01	0.15	2.32	35.26	19.40	100.00	0.00	1.24	33.33	1.24
1991	100.00	79.74	0.59	0.00	0.00	0.27	3.21	8.93	7.42	100.00	0.00	2.36	55.21	1.92
1992	0.00	100.00	3.24	0.00	0.01	2.01	9.36	3.56	4.08	0.00	0.00	0.70	0.00	0.70
1993	0.00	44.36	0.06	0.00	0.00	0.48	30.81	100.00	100.00	0.00	0.00	0.40	0.00	0.40
1994	0.00	0.00	0.00	0.01	1.01	4.41	0.73	2.25	0.00	0.00	0.00	0.40	0.00	0.40

Table B59 cont.

	0	1	2	3	4	5	6	7	8	9	10+	0+	9+	1+

1995	0.00	0.00	0.00	0.00	0.00	1.80	6.78	2.56	0.00	0.00	0.00	0.43	0.00	0.43
1996	0.00	0.00	0.00	0.26	1.89	0.10	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.47
1997	0.00	4.27	2.67	1.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.76	0.00	1.76
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2002	0.00	0.00	0.00	1.41	1.88	0.21	0.00	0.00	0.00	0.00	0.00	0.84	0.00	0.84
2003	0.00	1.83	2.00	3.42	0.63	0.00	0.00	0.00	0.00	0.00	0.00	1.56	0.00	1.56
2004	0.00	2.74	15.36	0.44	17.72	39.11	82.28	100.00	100.00	28.17	100.00	15.62	30.69	15.62
2005	0.00	0.00	0.00	0.36	4.44	0.79	0.36	0.26	2.42	18.42	0.00	1.45	7.66	1.47
2006	0.00	0.95	0.11	0.17	4.95	0.87	0.30	8.57	7.04	100.00	0.00	1.20	100.00	1.20
2007	0.00	3.63	2.77	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.26	0.00	1.26
2008	0.00	0.40	1.45	1.51	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.95	0.00	0.95
2009	0.00	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.08
2010	0.00	1.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.12
2011	100.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.07
2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table B60. Stratified mean number per tow at age of white hake in the NEFSC autumn bottom trawl surveys (Strata 21-30,36-40), 1963-2011. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+	0+	9+	1+	1+ Biomass
1963	**0.1483**	**0.9163**	**1.3741**	**1.4625**	**0.9796**	**0.3664**	**0.0749**	**0.0051**	**0.0112**	**0.0103**	**0.1197**	**5.4682**	**0.1299**	**5.3200**	**7.510**
1964	**0.0116**	**0.1195**	**0.4005**	**0.5308**	**0.3294**	**0.1365**	**0.0799**	**0.0314**	**0.0107**	**0.0084**	**0.1023**	**1.7610**	**0.1107**	**1.7495**	**4.088**
1965	**0.0394**	**0.3594**	**1.2753**	**1.2198**	**0.5949**	**0.3685**	**0.1976**	**0.0356**	**0.0174**	**0.0071**	**0.0454**	**4.1605**	**0.0525**	**4.1211**	**6.606**
1966	**0.1134**	**0.9573**	**3.1449**	**1.9368**	**0.8422**	**0.3313**	**0.1005**	**0.0604**	**0.0118**	**0.0038**	**0.0611**	**7.5634**	**0.0648**	**7.4500**	**8.394**
1967	**0.0990**	**0.7867**	**1.4079**	**1.0458**	**0.4231**	**0.1518**	**0.0617**	**0.0057**	**0.0020**	**0.0036**	**0.0353**	**4.0227**	**0.0389**	**3.9237**	**4.111**
1968	**0.1315**	**0.8621**	**1.1342**	**1.3397**	**0.6417**	**0.1696**	**0.0534**	**0.0168**	**0.0048**	**0.0000**	**0.0429**	**4.3968**	**0.0429**	**4.2653**	**4.872**
1969	**0.2438**	**1.7227**	**2.8094**	**2.5698**	**1.7583**	**0.6351**	**0.2271**	**0.0838**	**0.0419**	**0.0132**	**0.0417**	**10.1466**	**0.0549**	**9.9029**	**13.378**
1970	**0.0906**	**0.7893**	**1.9781**	**2.9890**	**2.0001**	**0.5626**	**0.2600**	**0.0576**	**0.0225**	**0.0306**	**0.0681**	**8.8484**	**0.0986**	**8.7578**	**14.162**
1971	**0.3838**	**2.9745**	**2.8858**	**2.2704**	**1.7146**	**0.4887**	**0.2189**	**0.0726**	**0.0350**	**0.0116**	**0.1402**	**11.1960**	**0.1518**	**10.8122**	**13.419**
1972	**0.2959**	**2.0370**	**4.5116**	**4.7995**	**1.2971**	**0.6470**	**0.2319**	**0.0580**	**0.0293**	**0.0464**	**0.0754**	**14.0291**	**0.1218**	**13.7332**	**14.525**
1973	**0.1568**	**0.9754**	**2.1076**	**3.5616**	**1.7131**	**0.6334**	**0.3390**	**0.0666**	**0.0539**	**0.0313**	**0.2238**	**9.8626**	**0.2551**	**9.7057**	**14.788**
1974	**0.0632**	**0.4037**	**0.8835**	**1.5748**	**1.3019**	**0.6457**	**0.2650**	**0.0718**	**0.0331**	**0.0059**	**0.1516**	**5.4001**	**0.1574**	**5.3369**	**12.114**
1975	**0.0877**	**0.5518**	**1.4646**	**1.6073**	**0.6914**	**0.3484**	**0.2253**	**0.0806**	**0.0212**	**0.0111**	**0.0570**	**5.1464**	**0.0681**	**5.0587**	**7.818**
1976	**0.0293**	**0.2125**	**1.2977**	**2.8008**	**1.3331**	**0.6003**	**0.2681**	**0.0610**	**0.0335**	**0.0070**	**0.0983**	**6.7417**	**0.1052**	**6.7124**	**11.694**
1977	**0.3862**	**1.8781**	**2.7485**	**2.8406**	**1.5926**	**0.5216**	**0.2906**	**0.1053**	**0.0554**	**0.0160**	**0.1405**	**10.5755**	**0.1565**	**10.1893**	**13.842**
1978	**0.1900**	**0.8696**	**2.5364**	**2.3629**	**1.1517**	**0.5905**	**0.3003**	**0.1228**	**0.0512**	**0.0305**	**0.1368**	**8.3427**	**0.1673**	**8.1526**	**13.312**
1979	**0.0122**	**0.2136**	**1.5249**	**1.9599**	**0.9664**	**0.4154**	**0.2372**	**0.0783**	**0.0255**	**0.0370**	**0.0901**	**5.5605**	**0.1272**	**5.5483**	**10.566**
1980	**1.0489**	**1.6777**	**1.4929**	**3.6967**	**2.3634**	**1.0263**	**0.3539**	**0.1359**	**0.0609**	**0.0154**	**0.1293**	**12.0013**	**0.1446**	**10.9524**	**18.400**
1981	**0.0414**	**0.5467**	**3.1291**	**1.9866**	**1.4891**	**0.7266**	**0.3310**	**0.1083**	**0.0511**	**0.0176**	**0.0008**	**8.4283**	**0.0184**	**8.3869**	**11.865**
1982	0.0070	0.3266	0.5433	0.6321	0.1867	0.1013	0.0589	0.0199	0.0000	0.0000	0.0000	1.8759	0.0000	1.8689	1.954
1983	0.0007	0.5977	3.1534	2.8528	1.8063	0.2370	0.2625	0.0028	0.0000	0.0000	0.0777	8.9909	0.0777	8.9902	11.513
1984	0.0000	0.3504	0.9706	2.1758	1.1276	0.3465	0.1040	0.0422	0.0116	0.0037	0.0402	5.1726	0.0439	5.1726	8.152
1985	0.2881	3.2732	1.7677	2.0369	1.3962	0.4317	0.1232	0.0748	0.0082	0.0000	0.0602	9.4601	0.0602	9.1720	9.784
1986	0.9522	1.2570	7.0940	4.3420	0.8370	0.4845	0.1536	0.0076	0.0024	0.0327	0.0178	15.1807	0.0505	14.2284	11.423
1987	0.0544	0.5487	1.8369	3.7714	1.0967	0.2195	0.1118	0.0633	0.0743	0.0208	0.0535	7.8514	0.0743	7.7970	9.799
1988	0.0076	0.5593	3.9489	2.1881	1.3588	0.3180	0.1032	0.0043	0.0003	0.0000	0.0511	8.5397	0.0511	8.5321	10.430
1989	0.4012	3.3810	3.3155	3.7846	0.9140	0.3685	0.3513	0.0100	0.0084	0.0036	0.0000	12.5381	0.0036	12.1369	9.242

Table B60. cont.

	0	1	2	3	4	5	6	7	8	9	10+	0+	9+	1+	1+ Biomass
1990	1.0209	1.9769	5.3091	3.8259	1.3655	0.3219	0.0382	0.0000	0.0013	0.0012	0.0000	13.8610	0.0012	12.8401	10.883
1991	0.1828	1.1574	6.1843	4.3646	1.3777	0.3424	0.0479	0.0000	0.0075	0.0000	0.0075	13.6721	0.0075	13.4894	12.533
1992	0.1600	0.4178	2.5760	5.8455	1.3604	0.1712	0.1117	0.0447	0.0365	0.0000	0.0224	10.7462	0.0224	10.5862	11.837
1993	0.0503	0.6632	2.3969	4.3012	2.5471	0.4324	0.1128	0.0000	0.0000	0.0000	0.0000	10.5040	0.0000	10.4537	12.038
1994	0.3155	1.0167	2.5558	2.4494	0.7570	0.1554	0.1116	0.0191	0.0000	0.0000	0.0000	7.3805	0.0000	7.0650	5.924
1995	1.3309	0.5887	4.2878	2.8038	0.7044	0.1883	0.0035	0.1312	0.0024	0.0000	0.0309	10.0719	0.0309	8.7410	8.438
1996	0.0272	0.3366	1.0406	1.5485	1.2708	0.3642	0.0314	0.0224	0.0283	0.0000	0.0141	4.6840	0.0141	4.6568	6.651
1997	0.0000	1.7997	1.2606	0.9787	0.6282	0.2034	0.0606	0.0141	0.0224	0.0000	0.0635	5.0312	0.0635	5.0312	4.896
1998	0.0385	0.4267	1.9725	1.6966	0.5376	0.1581	0.0839	0.0258	0.0181	0.0000	0.0000	4.9577	0.0000	4.9193	4.736
1999	0.3680	2.4981	1.2990	1.1923	0.5449	0.1790	0.0686	0.0040	0.0000	0.0000	0.0000	6.1538	0.0000	5.7858	3.637
2000	0.1343	0.5037	3.6025	2.0934	0.6905	0.3064	0.0994	0.0425	0.0418	0.0284	0.0256	7.5686	0.0539	7.4343	6.796
2001	0.0554	0.2809	0.9877	2.0550	1.7167	0.3762	0.1513	0.0807	0.0000	0.0000	0.0000	5.7039	0.0000	5.6485	7.848
2002	2.6038	1.1791	0.7503	1.0023	1.0124	0.1883	0.0744	0.0365	0.0000	0.0000	0.0141	6.8612	0.0141	4.2574	6.404
2003	**0.1663**	**1.1062**	**0.7510**	**0.9807**	**0.6469**	**0.1889**	**0.1391**	**0.0468**	**0.0040**	**0.0008**	**0.0000**	**4.0307**	**0.0008**	**3.8644**	**4.513**
2004	0.1156	0.7650	1.2654	0.6742	0.3438	0.2193	0.1342	0.0042	0.0103	0.0178	0.0000	3.5497	0.0178	3.4341	3.685
2005	0.5378	0.9182	0.5663	0.5928	0.4060	0.3008	0.0554	0.1180	0.0380	0.0085	0.0432	3.5850	0.0517	3.0472	3.791
2006	0.3114	1.8079	1.0044	0.8612	0.2523	0.2030	0.1421	0.0607	0.0836	0.0000	0.0246	4.7511	0.0246	4.4396	4.238
2007	0.3002	0.7998	1.9491	2.3556	0.8915	0.1891	0.0079	0.0188	0.0461	0.0727	0.0050	6.6358	0.0777	6.3356	7.202
2008	1.4540	0.8485	1.5986	2.0292	0.9903	0.1900	0.0872	0.0815	0.0455	0.0201	0.0000	7.3448	0.0201	5.8908	6.977
2009	0.5664	0.9923	1.5266	1.2441	0.6367	0.2524	0.0608	0.0220	0.0073	0.0000	0.0184	5.3270	0.0184	4.7606	4.709
2010	0.8141	1.6021	2.6998	1.9203	0.6548	0.1672	0.0581	0.0100	0.0139	0.0074	0.0037	7.9514	0.0111	7.1373	7.761
2011	0.3397	0.6251	2.1497	2.0349	1.1169	0.4062	0.1619	0.0590	0.0341	0.0069	0.0109	6.9454	0.0178	6.6056	8.991

Table B61. Proportion of the autumn survey catch at age of white hake that was imputed. The values in bold were computed using a pooled ALK.

	0	1	2	3	4	5	6	7	8	9	10+	0+	9+	1+
1963	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**13.23**	**0.29**	**12.18**	**0.30**
1964	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**56.02**	**3.25**	**51.75**	**3.28**
1965	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**98.37**	**1.07**	**85.02**	**1.08**
1966	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**86.13**	**0.70**	**81.14**	**0.71**
1967	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1968	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**64.79**	**0.63**	**64.79**	**0.65**
1969	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**63.37**	**0.26**	**48.14**	**0.27**
1970	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**29.21**	**0.22**	**20.16**	**0.23**
1971	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**60.95**	**0.76**	**56.28**	**0.79**
1972	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**18.74**	**0.10**	**11.60**	**0.10**
1973	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**64.72**	**1.47**	**56.78**	**1.49**
1974	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**67.47**	**1.89**	**64.95**	**1.92**
1975	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**34.85**	**0.39**	**29.20**	**0.39**
1976	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**55.41**	**0.81**	**51.74**	**0.81**
1977	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**51.22**	**0.68**	**45.98**	**0.71**
1978	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**43.09**	**0.71**	**35.23**	**0.72**
1979	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**68.30**	**1.11**	**48.42**	**1.11**
1980	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**66.74**	**0.72**	**59.65**	**0.79**
1981	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
1982	28.95	53.04	50.42	50.32	57.59	54.33	50.86	50.00	0.00	0.00	0.00	51.69	0.00	51.78
1983	100.00	0.66	0.00	0.00	0.10	5.95	7.51	100.00	0.00	0.00	0.00	0.48	0.00	0.47
1984	0.00	0.00	0.00	0.00	0.07	4.00	27.99	39.04	32.00	100.00	0.00	1.31	8.49	1.31
1985	10.42	0.00	0.00	0.00	0.00	0.74	32.20	54.81	100.00	0.00	37.42	1.53	37.42	1.25
1986	77.59	18.35	0.00	0.00	0.00	0.49	2.30	77.97	100.00	0.00	0.00	6.48	0.00	1.72
1987	3.28	2.15	0.02	0.00	0.99	4.80	6.62	9.38	28.00	14.29	33.33	1.15	28.00	1.13
1988	100.00	2.45	0.00	0.00	0.19	5.23	28.88	100.00	100.00	0.00	0.00	0.88	0.00	0.79
1989	100.00	5.08	2.10	0.00	0.11	1.71	4.37	100.00	100.00	100.00	0.00	5.48	100.00	2.36

Table B61. cont.

	0	1	2	3	4	5	6	7	8	9	10+	0+	9+	1+
1990	16.30	0.60	0.00	0.00	0.68	8.16	41.30	0.00	100.00	100.00	0.00	1.68	100.00	0.51
1991	0.00	0.00	0.00	0.00	0.00	0.00	15.56	0.00	100.00	0.00	100.00	0.16	100.00	0.17
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1995	0.00	0.00	0.00	0.00	0.00	1.25	100.00	4.49	100.00	0.00	0.00	0.14	0.00	0.16
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.19	0.44	35.19	0.44
1998	0.00	0.00	0.00	0.00	0.54	8.02	2.91	1.89	0.00	0.00	0.00	0.37	0.00	0.38
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2000	29.55	0.00	0.00	0.00	0.00	0.00	2.84	6.65	13.51	9.96	0.00	0.71	5.24	0.19
2001	1.79	3.14	2.54	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.62
2002	0.00	0.21	1.66	0.71	0.00	0.00	0.00	0.00	0.00	0.00	100.00	0.53	100.00	0.85
2003	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
2004	2.16	2.37	0.06	0.79	2.73	0.05	5.79	100.00	13.67	0.00	0.00	1.40	0.00	1.37
2005	0.28	1.07	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35	0.00	0.37
2006	5.43	3.15	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.70	0.00	1.44
2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	30.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.02	0.00	0.00
2009	3.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2011	1.64	0.26	0.00	0.00	0.00	0.00	0.35	0.96	3.32	8.22	0.00	0.14	3.18	0.07

Table B62. Age composition of the Massachusetts spring survey using NEFSC age-length keys.

	0	1	2	3	4	5
1982	0.07516	0.207814	0.071543	0.020022	0.000591	0
1983	0.4288	0.203524	0.436186	0.01888	0	0
1984	0.06611	0.94927	0.01091	0.04146	0	0
1985	1.51467	0.034927	0.069231	0.013652	0	0
1986	0.21808	0.063285	1.836168	0.494817	0	0
1987	0	0.042213	0.194027	0.00532	0	0
1988	0.13093	0.073923	0.220568	0.000709	0	0
1989	0.06601	0.139311	0.298507	0.116062	0	0
1990	0.05455	0.266413	0.72946	0.026377	0	0.00546
1991	0.04092	0.078934	0.242576	0.015354	0.000266	0
1992	0.46427	0.041836	0.097148	0.024963	0.001773	0
1993	0.34278	0	0	0.006617	0.000473	0
1994	0.30418	0.069568	0.049602	0.01488	0	0
1995	0.34242	0.058177	0.1432	0.017733	0	0
1996	1.08034	0	0	0	0	0
1997	0.30772	0.084093	0.149117	0.01146	0	0
1998	0.29569	0.004077	0.068487	0.000546	0	0
1999	0.10481	0.051394	0.043086	0	0	0
2000	0.47073	0.053475	0.167861	0.005624	0	0
2001	0.34396	0.012	0.01026	0	0	0
2002	1.51688	0.023349	0.047584	0.007803	0.004256	0.002128
2003	0.70017	0.01146	0.00618	0	0	0
2004	0.02094	0.048504	0.020523	5.28E-05	0	0
2005	0.04928	0.01042	0.006	0	0	0
2006	0.04834	0.556437	0.114454	0.017142	0.003547	0
2007	0	0.212179	0.157751	0.00647	0.00532	0
2008	0	0.120205	0.003015	0.00912	0.00152	0
2009	0	0.194623	0.008047	0	0	0
2010	0	0.166931	0.093366	0.005943	0	0
2011	0	0.020243	0.010307	0	0	0
2012	0	0.015739	0.063917	0.025094	0	0

Table B63. Age composition of the Massachusetts autumn survey using NEFSC age-length keys.

	0	1	2	3	4	5
1982	1.434322	3.259932	0.383718	0.117087	0.007081	0
1983	0.242258	0.777131	0.429525	0.015566	0	0
1984	0.184489	0.420558	0.032423	0	0	0
1985	11.0301	0.634931	0.073998	0.005625	0.00269	0
1986	0.686212	0.254491	0.264147	0.04153	0.00753	0
1987	3.438198	0.148237	0.118555	0	0	0
1988	0.720909	0.527342	0.287022	0.010887	0	0
1989	3.409851	0.939125	0.115098	0.006126	0	0
1990	1.295296	0.805554	1.051204	0.000945	0	0
1991	0.595138	0.549544	0.345681	0.037797	0	0
1992	3.22495	1.072206	0.083106	0.010795	0.000273	0
1993	2.494101	2.446865	0.093193	0.002191	0	0
1994	1.30706	1.662072	0.498832	0.014836	0	0
1995	14.73499	0.397407	0.085654	0.000692	0	0
1996	2.46074	1.61933	0.04172	0	0	0
1997	0.40524	0.51648	0.11423	0	0	0
1998	0.876202	0.310138	0.009	0	0	0
1999	4.353209	1.627061	0.071804	0.006207	0	0
2000	0.505006	0.138872	0.148588	0.001794	0	0
2001	1.596072	0.080838	0.00456	0.010364	0.005389	0.000967
2002	0.376809	0.083735	0.064719	0.023053	0.007093	0
2003	0.756828	0.076554	0.001288	0	0	0
2004	1.125531	0.084843	0.006506	0	0	0
2005	0.723108	0.154428	0.010024	0.00532	0	0
2006	0.210005	0.212323	0.050486	0.051585	0	0
2007	0.334401	0.159162	0.042066	0.000651	0	0
2008	0.089972	0.051948	0.022606	0.027284	0.006029	0
2009	3.901106	0.500478	0.027169	0.011267	0	0
2010	0.701364	0.180642	0.024624	0	0	0
2011	5.567023	0.219195	0.093404	0.015108	0.00304	0

Table B64. Age composition of the ME/NH surveys using length-slicing.

Spring

	Age 0	Age 1	2+	1+	1+ Biomass
	<=9 CM	10-33 CM	>35 CM	>=19	
2001	0	0.656	0	0.656	0.044
2002	0.123	1.897	0.085	1.981	0.281
2003	0	1.801	0.141	1.942	0.363
2004	0	2.376	0.012	2.388	0.174
2005	0	3.698	0.533	4.231	0.619
2006	0	5.930	0.184	6.114	0.553
2007	0	3.790	0.316	4.106	0.478
2008	0.010	6.515	0.267	6.782	0.763
2009	0.190	15.027	0.167	15.194	1.157
2010	0.013	2.191	0.284	2.476	0.373
2011	0.084	3.717	0.048	3.765	0.439
2012	0	2.688	0.330	3.018	0.481

Autumn

Fall	Age 0	Age 1	Age 2	Age 3+	1+	1+ Biomass
	<=18 CM	19-29 CM	30-41 CM	>41CM	>=19	
2000	10.489	6.782	2.234	0.191	9.207	1.543
2001	15.430	12.744	2.721	0.554	16.019	2.769
2002	0	18.264	1.422	0.220	19.907	2.628
2003	0.109	18.964	3.230	0.544	22.738	3.646
2004	0.174	8.596	3.637	0.298	12.531	2.665
2005	0.041	14.593	1.627	0	16.220	1.981
2006	0.415	7.946	2.644	0.186	10.776	1.859
2007	0.058	15.294	6.230	0.700	22.224	3.991
2008	0.501	16.967	6.273	0.671	23.911	4.392
2009	0.063	24.819	6.066	0.486	31.371	4.558
2010	0.760	10.085	2.453	0.374	12.911	2.187
2011	2.457	20.007	2.707	0.792	23.506	4.045

Table B65. Summary of the number of white hake maturity samples taken from Northeast Fisheries Science Center (NEFSC) spring survey from 1982 to 2011 by year and the resulting maturity at age vector for females used in the assessment.

Year	Males	Females		Age	Proportion mature
1982	42	70		1	0.06
1983	67	73		2	0.22
1984	18	50		3	0.57
1985	74	97		4	0.86
1986	117	149		5	0.97
1987	72	73		6	0.99
1988	60	74		7	1.00
1989	43	54		8	1.00
1990	65	147		9	1.00
1991	100	143			
1992	50	97			
1993	66	90			
1994	52	48			
1995	39	57			
1996	42	48			
1997	32	23			
1998	40	49			
1999	51	55			
2000	72	83			
2001	62	63			
2002	36	69			
2003	64	76			
2004	31	23			
2005	35	39			
2006	53	42			
2007	25	24			
2008	64	70			
2009	170	190			
2010	152	174			
2011	138	180			

Table B67. Percent difference between the age composition of the commercial catch (A), spring survey (B) and autumn survey (C) used in the pooled ALK study.

A.	1	2	3	4	5	6	7	8	9
1989	4.1	-0.6	-3.1	17.7	-12.1	-24.6	18.4	-139.2	24.0
1990	15.3	-5.6	3.5	0.8	13.6	18.8	-69.0	4.6	4.8
1991	-13.4	1.2	1.8	-2.0	6.9	-15.6	-43.0	-44.2	18.5
1992	16.3	20.2	-8.5	-39.4	35.8	27.1	-54.8	4.7	43.5
1993	11.9	-7.4	3.8	-12.9	20.8	-0.9	41.7	40.5	23.3
1994	6.6	11.9	-5.9	-1.5	7.3	-34.2	4.3	4.7	44.5
1995	-2.1	-10.4	8.8	14.3	-17.6	-63.0	-103.5	-48.1	-264.8
1996	-11.5	10.1	1.1	20.7	-7.1	-67.4	-151.9	-145.8	16.9
1997	-1.3	-0.3	3.7	35.5	-6.5	-43.2	-213.6	-223.8	-53.9
1998	1.7	-6.8	8.7	26.0	28.0	-13.0	-178.5	-63.1	91.6
1999	1.4	25.2	-23.7	30.6	-6.5	-9.7	-64.0	-89.5	-145.2
2000	29.9	0.4	-1.4	34.4	-3.5	1.5	-15.9	-101.1	-175.4

B.	1	2	3	4	5	6	7	8	9
1982	-18.9	-12.6	-9.4	29.6	-25.7	42.0	69.2	32.8	2.7
1983	13.8	-7.9	-7.3	9.2	40.6	-17.9	-3.5	-15.6	100.0
1984	5.0	-0.7	-21.2	20.8	7.7	0.7	16.8	-77.7	-21.2
1985	-219.4	-8.4	-5.8	8.1	14.7	18.2	12.3	10.0	7.4
1986	4.8	-1.8	-0.5	5.5	-17.5	20.7	100.0	-4.9	100.0
1987	20.3	-18.2	-8.8	26.1	19.9	24.4	100.0	-60.6	16.0
1988	-112.2	5.1	2.4	1.6	1.4	-3.2	54.2	-407.2	-169.2
1989	-51.4	-4.2	-5.4	37.0	-13.2	6.2	31.3	100.0	100.0
1990	-233.3	5.2	1.7	-17.5	15.9	47.6	-12.0	-49.5	8.0
1991	-83.2	1.6	20.9	-23.8	-44.3	-47.4	-112.6	-100.0	7.0
1992	100.0	40.2	32.4	-105.9	25.2	43.6	-51.8	47.4	100.0
1993	40.6	-9.7	-2.9	-9.3	41.1	80.5	100.0	100.0	100.0
1994	43.9	6.8	-9.8	1.0	0.1	-10.1	52.7	14.4	100.0
1995	-59.2	17.9	-13.9	5.1	20.6	-52.0	41.9	-108.5	100.0
1996	-74.8	6.5	-6.3	18.3	-13.8	-42.2	-23.4	11.0	-17.1
1997	-174.8	-1.2	0.3	3.6	-8.8	100.0			100.0
1998	-30.0	-12.9	3.9	31.5	13.6	28.2	100.0	100.0	100.0
1999	-346.8	14.0	-11.4	11.1	-5.1	11.5	-203.0	-105.1	100.0
2000	-320.6	5.2	-13.1	16.2	27.6	-63.2	-650.0		100.0

C.	1	2	3	4	5	6	7	8	9
1982	-13.7	1.1	0.7	18.0	-13.4	-34.5	-33.6	100.0	100.0
1983	-19.0	3.5	0.3	-8.0	30.9	-58.0	88.7	100.0	0.1
1984	-7.6	0.4	-1.8	-6.0	15.6	14.0	47.7	38.9	5.2
1985	-1.3	6.8	13.1	-26.6	-2.2	31.4	12.4	-21.9	0.0
1986	4.6	-3.0	5.5	7.5	-31.2	26.9	-68.2	100.0	-83.1
1987	1.2	12.0	-10.7	11.5	13.9	-5.8	3.0	-20.9	-13.7
1988	12.8	-6.0	7.7	0.7	-24.7	-6.5	100.0	100.0	5.1
1989	-1.1	8.0	-5.5	-3.5	8.2	-85.1	-7.6	-81.5	-83.9
1990	-2.3	-7.1	2.8	10.1	8.3	80.6	100.0		
1991	-8.7	-1.9	-4.3	8.6	39.5	67.8	100.0	-201.5	100.0
1992	12.8	15.4	-13.8	8.6	38.0	10.6	37.1	-128.2	11.3
1993	12.7	12.4	-5.4	-19.7	-4.0	-26.8	100.0	100.0	
1994	19.8	1.4	-8.9	-4.2	12.9	-40.5	-28.3	100.0	
1995	-13.2	-17.5	15.3	12.5	-8.1	81.8	-48.4	100.0	12.7
1996	-1.7	-8.6	1.7	7.7	-26.1	40.9	5.5	-16.4	-64.9
1997	-2.9	-4.8	9.2	-0.6	1.1	-48.5	29.9	-600.0	0.0
1998	10.6	5.5	-9.7	10.8	-25.1	-79.9	-31.3	-48.6	100.0
1999	-11.6	11.4	-5.4	9.5	-109.6	-193.6	10.3	100.0	
2000	-7.2	-1.6	6.8	9.4	-82.7	-90.8	-31.0	-61.0	1.2

Table B67. Results and diagnostics from the VPA model configurations.

Age	Unpooled ALK Stock Size	CV	Pooled Commercial ALK Stock Size	CV	Pooled Survey ALK Stock Size	CV	Pooled Commercial and Survey ALKs Stock Size	CV
2	4,199	0.75	4,143	0.70	4,026	0.93	3,985	0.85
3	7,954	0.49	7,779	0.46	7,370	0.61	7,235	0.56
4	1,373	0.55	1,308	0.52	1,386	0.68	1,326	0.64
5	721	0.48	634	0.48	692	0.60	608	0.59
6	147	0.58	137	0.55	113	0.76	108	0.71
7	68	0.63	49	0.62	38	0.85	27	0.81
INDEX	Catchability	CV	Catchability	CV	Catchability	CV	Catchability	CV
Spring Age 2	0.00015	0.11	0.00016	0.11	0.00017	0.09	0.00017	0.09
Spring Age 3	0.00040	0.10	0.00042	0.10	0.00041	0.08	0.00042	0.08
Spring Age 4	0.00042	0.21	0.00043	0.21	0.00044	0.17	0.00045	0.16
Spring Age 5	0.00036	0.30	0.00040	0.28	0.00040	0.31	0.00044	0.29
Spring Age 6	0.00025	0.34	0.00033	0.33	0.00021	0.45	0.00029	0.40
Spring Age 7	0.00021	0.33	0.00034	0.32	0.00010	0.59	0.00016	0.57
Fall Age 1	0.00012	0.16	0.00012	0.16	0.00013	0.16	0.00013	0.16
Fall Age 2	0.00057	0.11	0.00059	0.10	0.00059	0.10	0.00060	0.09
Fall Age 3	0.00131	0.06	0.00135	0.07	0.00132	0.06	0.00136	0.06
Fall Age 4	0.00117	0.10	0.00132	0.09	0.00124	0.09	0.00140	0.07
Fall Age 5	0.00073	0.18	0.00099	0.15	0.00075	0.21	0.00101	0.17
Fall Age 6	0.00048	0.34	0.00078	0.29	0.00059	0.31	0.00096	0.27

Table B68. Results of the ASAP model formulations

Run		Unpooled ALK	Pooled survey ALk	Pooled Commercial ALK	Pooled Commercial and Survey ALK
SSB1982 (mt)		10971	11904	10174	11043
SSB2000 (mt)		4641	4555	4789	4677
Fmult, 2000		0.98	1.01	0.98	1.02
Selectivity					
Spring Survey	1	0.01	0.01	0.01	0.01
	2	0.19	0.20	0.17	0.17
	3	0.54	0.55	0.49	0.49
	4	0.73	0.72	0.66	0.66
	5	1.00	1.00	1.00	1.00
	6	0.96	1.00	1.00	1.00
	7	0.62	0.66	0.71	0.76
	8	1.00	1.00	1.00	1.00
	9	1.00	1.00	1.00	1.00
Fall Survey	1	0.07	0.08	0.06	0.07
	2	0.28	0.31	0.25	0.27
	3	0.68	0.71	0.59	0.63
	4	0.80	0.83	0.73	0.76
	5	1.00	1.00	1.00	1.00
	6	0.93	0.85	1.00	0.94
	7	0.70	0.76	0.76	0.83
	8	0.77	0.77	0.78	0.79
	9	1.00	1.00	1.00	1.00
Commercial	1	0.07	0.07	0.06	0.06
	2	0.27	0.27	0.26	0.26
	3	0.60	0.59	0.54	0.54
	4	0.77	0.75	0.74	0.73
	5	1.00	1.00	1.00	1.00
	6	0.73	0.74	0.73	0.75
	7	0.61	0.68	0.49	0.58
	8	0.69	0.70	0.58	0.59
	9	0.50	0.53	0.44	0.46

Table B69. Results from the retrospective analyses for the eight model configurations for fishing mortality (F), spawning stock biomass (SSB) and recruitment. The relative differences by year are given as well as the average for the model.

VPA				ASAP			
Unpooled	F	SSB	Recruitment		F	SSB	Recruitment
1994	0.61	-0.24	0.70	1994	-0.35	0.38	1.18
1995	1.84	-0.37	0.27	1995	-0.38	0.42	0.76
1996	2.19	-0.48	0.06	1996	-0.34	0.39	0.69
1997	2.25	-0.60	0.40	1997	-0.07	0.04	1.73
1998	1.00	-0.36	-0.24	1998	0.19	-0.17	0.30
1999	0.68	-0.27	0.16	1999	0.02	-0.03	0.53
Average	1.43	-0.38	0.23	Average	-0.15	0.17	0.87
Pooled Commercial ALK							
1994	-0.01	0.04	0.68	1994	-0.40	0.52	1.17
1995	0.58	-0.10	0.20	1995	-0.43	0.59	0.78
1996	1.01	-0.27	-0.01	1996	-0.41	0.56	0.71
1997	1.75	-0.51	0.52	1997	-0.17	0.15	1.89
1998	0.97	-0.34	-0.27	1998	0.11	-0.11	0.32
1999	0.69	-0.23	0.17	1999	-0.04	0.02	0.60
Average	0.83	-0.24	0.21	Average	-0.22	0.29	0.91
Pooled Survey ALK							
1994	0.75	-0.27	0.97	1994	-0.39	0.49	2.12
1995	1.61	-0.34	0.17	1995	-0.41	0.53	0.43
1996	3.14	-0.57	-0.02	1996	-0.37	0.46	0.43
1997	3.54	-0.63	0.25	1997	-0.09	0.07	1.70
1998	1.64	-0.43	-0.21	1998	0.19	-0.16	0.28
1999	1.42	-0.36	0.13	1999	0.07	-0.07	0.41
Average	2.01	-0.43	0.21	Average	-0.17	0.22	0.90
Pooled Commercial and Survey ALK							
1994	0.08	0.00	0.93	1994	-0.43	0.64	2.09
1995	0.46	-0.07	0.10	1995	-0.47	0.71	0.45
1996	1.81	-0.43	-0.09	1996	-0.44	0.64	0.44
1997	2.74	-0.54	0.35	1997	-0.19	0.18	1.86
1998	1.51	-0.39	-0.24	1998	0.11	-0.11	0.30
1999	1.46	-0.32	0.13	1999	0.00	-0.01	0.47
Average	1.34	-0.30	0.20	Average	-0.24	0.34	0.93

Table B70. Biological reference points estimated from VPA and ASAP models.

VPA	Unpooled ALK	Pooled Commercial ALK	Pooled Survey ALK	Pooled Commercial and Survey ALKs
F40	0.13	0.16	0.13	0.16
SSBMSY	60,400	61,200	59,600	60,500
F2000	0.94	1.07	1.22	1.36
SSB2000	5,922	5,260	5,204	4,731
F/Fmsy	6.96	6.86	9.05	8.50
SSB/SSBmsy	0.10	0.09	0.09	0.08

External ASAP				
F40	0.20	0.22	0.20	0.22
SSBMSY	75,600	77,500	73,400	75,600
F2000	0.74	0.70	0.78	0.74
SSB2000	4,641	4,789	4,555	4,677
F/Fmsy	3.75	3.17	4.01	3.43
SSB/SSBmsy	0.06	0.06	0.06	0.06

Internal ASAP				
F40	0.15	0.15	0.15	0.15
Fmsy	0.24	0.24	0.24	0.25
SSBmsy	39,645	44,679	38,753	43,582
F2000	0.74	0.70	0.78	0.74
SSB2000	4,641	4,789	4,555	4,677
F/F40	5.11	4.72	5.38	4.96
F/Fmsy	3.07	2.85	3.24	3.00
SSB/SSBmsy	0.12	0.11	0.12	0.11

Table B71. Coefficient of Variation in Starting Numbers-at-age from an early ASAP run.

Age	CV
2	0.16
3	0.17
4	0.19
5	0.30
6	0.39
7	0.57
8	1.00
9	0.19

Table B72. Results of the Base ASAP Model.

	SSB (mt)	Jan 1 Biomass (mt)	Fishing mortality	Numbers at Age 1 (000s)
1963	16,736	20,085	0.31	3,410
1964	16,157	19,181	0.29	2,837
1965	15,574	18,460	0.27	3,947
1966	15,298	18,024	0.20	4,505
1967	15,999	18,872	0.15	4,807
1968	17,541	20,773	0.14	5,745
1969	19,600	23,005	0.12	4,948
1970	22,119	25,937	0.14	6,460
1971	24,444	28,803	0.16	7,867
1972	26,504	31,018	0.15	5,025
1973	29,261	33,685	0.14	4,652
1974	31,960	36,382	0.16	5,673
1975	33,441	37,690	0.14	4,666
1976	34,399	38,831	0.15	4,819
1977	34,117	39,023	0.19	6,439
1978	32,932	37,992	0.19	6,369
1979	32,197	37,036	0.18	3,587
1980	31,565	36,514	0.20	6,571
1981	30,073	35,268	0.27	5,315
1982	27,260	32,789	0.33	6,192
1983	24,104	29,141	0.34	3,797
1984	21,532	26,475	0.41	5,620
1985	18,594	24,072	0.49	10,827
1986	15,507	21,057	0.54	5,768
1987	13,775	19,558	0.64	8,792
1988	13,033	18,573	0.64	8,553
1989	12,313	17,715	0.62	12,468
1990	12,491	18,480	0.65	13,072
1991	12,724	18,933	0.57	8,109
1992	13,700	20,355	0.89	6,998
1993	11,570	16,975	1.07	6,673
1994	8,894	12,289	0.76	4,492
1995	7,896	11,025	0.71	2,781
1996	7,891	10,485	0.55	3,520
1997	7,847	9,873	0.36	4,596
1998	9,043	11,010	0.35	4,630
1999	9,413	12,254	0.50	6,231
2000	9,192	11,519	0.46	2,670
2001	10,438	12,599	0.47	2,332
2002	12,556	15,275	0.35	2,506
2003	13,322	16,098	0.46	2,458
2004	12,999	15,423	0.35	2,296
2005	11,577	14,897	0.31	3,841
2006	11,134	13,579	0.19	4,946
2007	14,205	16,744	0.13	4,047
2008	15,888	19,225	0.12	5,053
2009	16,017	19,148	0.14	5,672
2010	21,106	24,626	0.11	5,898
2011	26,877	31,225	0.13	4,006

Table B73. Fishing mortality by age from the Base ASAP model.

	1	2	3	4	5	6	7	8	9+
1963	0.02	0.06	0.14	0.23	0.27	0.31	0.31	0.31	0.31
1964	0.02	0.05	0.13	0.21	0.26	0.29	0.29	0.29	0.29
1965	0.02	0.05	0.12	0.20	0.24	0.27	0.27	0.27	0.27
1966	0.01	0.04	0.09	0.14	0.17	0.20	0.20	0.20	0.20
1967	0.01	0.03	0.07	0.11	0.13	0.15	0.15	0.15	0.15
1968	0.01	0.03	0.06	0.10	0.12	0.14	0.14	0.14	0.14
1969	0.01	0.02	0.05	0.09	0.11	0.12	0.12	0.12	0.12
1970	0.01	0.03	0.06	0.10	0.12	0.14	0.14	0.14	0.14
1971	0.01	0.03	0.07	0.11	0.14	0.16	0.16	0.16	0.16
1972	0.01	0.03	0.07	0.11	0.13	0.15	0.15	0.15	0.15
1973	0.01	0.03	0.06	0.10	0.12	0.14	0.14	0.14	0.14
1974	0.01	0.03	0.07	0.11	0.13	0.16	0.16	0.16	0.16
1975	0.01	0.03	0.06	0.10	0.12	0.14	0.14	0.14	0.14
1976	0.01	0.03	0.07	0.11	0.13	0.15	0.15	0.15	0.15
1977	0.01	0.04	0.09	0.14	0.17	0.19	0.19	0.19	0.19
1978	0.01	0.04	0.09	0.14	0.17	0.19	0.19	0.19	0.19
1979	0.01	0.03	0.08	0.13	0.15	0.18	0.18	0.18	0.18
1980	0.01	0.04	0.09	0.15	0.18	0.20	0.20	0.20	0.20
1981	0.02	0.05	0.12	0.20	0.23	0.27	0.27	0.27	0.27
1982	0.02	0.06	0.15	0.24	0.29	0.33	0.33	0.33	0.33
1983	0.02	0.06	0.15	0.25	0.30	0.34	0.34	0.34	0.34
1984	0.02	0.08	0.18	0.30	0.35	0.41	0.41	0.41	0.41
1985	0.03	0.09	0.22	0.36	0.43	0.49	0.49	0.49	0.49
1986	0.03	0.10	0.24	0.39	0.47	0.54	0.54	0.54	0.54
1987	0.04	0.12	0.29	0.47	0.56	0.64	0.64	0.64	0.64
1988	0.04	0.12	0.29	0.47	0.56	0.64	0.64	0.64	0.64
1989	0.04	0.11	0.28	0.45	0.54	0.62	0.62	0.62	0.62
1990	0.04	0.12	0.29	0.47	0.56	0.65	0.65	0.65	0.65
1991	0.03	0.11	0.26	0.42	0.50	0.57	0.57	0.57	0.57
1992	0.05	0.16	0.40	0.65	0.77	0.89	0.89	0.89	0.89
1993	0.06	0.20	0.48	0.78	0.93	1.07	1.07	1.07	1.07
1994	0.05	0.14	0.34	0.56	0.66	0.76	0.76	0.76	0.76
1995	0.04	0.13	0.32	0.52	0.61	0.71	0.71	0.71	0.71
1996	0.03	0.10	0.25	0.40	0.47	0.55	0.55	0.55	0.55
1997	0.02	0.07	0.16	0.26	0.31	0.36	0.36	0.36	0.36
1998	0.04	0.05	0.09	0.17	0.23	0.35	0.35	0.35	0.35
1999	0.05	0.07	0.13	0.24	0.33	0.50	0.50	0.50	0.50
2000	0.05	0.07	0.12	0.23	0.31	0.46	0.46	0.46	0.46
2001	0.05	0.07	0.12	0.23	0.31	0.47	0.47	0.47	0.47
2002	0.04	0.05	0.09	0.17	0.23	0.35	0.35	0.35	0.35
2003	0.05	0.07	0.12	0.23	0.31	0.46	0.46	0.46	0.46
2004	0.04	0.05	0.09	0.17	0.23	0.35	0.35	0.35	0.35
2005	0.03	0.04	0.08	0.15	0.21	0.31	0.31	0.31	0.31
2006	0.02	0.03	0.05	0.09	0.13	0.19	0.19	0.19	0.19
2007	0.01	0.02	0.03	0.06	0.08	0.13	0.13	0.13	0.13
2008	0.01	0.02	0.03	0.06	0.08	0.12	0.12	0.12	0.12
2009	0.02	0.02	0.04	0.07	0.09	0.14	0.14	0.14	0.14
2010	0.01	0.02	0.03	0.05	0.07	0.11	0.11	0.11	0.11
2011	0.01	0.02	0.04	0.06	0.09	0.13	0.13	0.13	0.13

Table B74. Numbers at age (000s) from the Base ASAP model.

	1	2	3	4	5	6	7	8	9+
1963	3410	2883	2558	2145	1415	849	511	327	509
1964	2837	2740	2226	1817	1396	882	507	306	500
1965	3947	2282	2124	1596	1201	886	538	310	491
1966	4505	3178	1775	1536	1069	774	551	335	498
1967	4807	3645	2509	1330	1089	738	520	370	560
1968	5745	3900	2902	1919	975	782	519	366	655
1969	4948	4664	3111	2230	1418	707	557	370	727
1970	6460	4022	3733	2411	1671	1045	513	404	795
1971	7867	5245	3208	2869	1783	1212	744	365	853
1972	5025	6381	4171	2447	2096	1274	848	521	853
1973	4652	4078	5081	3192	1797	1507	898	598	968
1974	5673	3777	3253	3905	2360	1302	1073	639	1115
1975	4666	4602	3004	2483	2855	1688	913	752	1230
1976	4819	3789	3671	2309	1835	2070	1202	650	1410
1977	6439	3910	3017	2809	1695	1320	1459	847	1452
1978	6369	5211	3088	2263	1997	1173	890	985	1551
1979	3587	5154	4115	2316	1608	1381	791	600	1709
1980	6571	2906	4085	3113	1669	1131	949	543	1587
1981	5315	5314	2291	3050	2196	1144	755	634	1422
1982	6192	4282	4139	1661	2053	1424	716	473	1287
1983	3797	4969	3296	2917	1068	1260	837	421	1034
1984	5620	3046	3818	2313	1862	650	733	487	846
1985	10827	4490	2312	2600	1406	1070	354	399	726
1986	5768	8605	3354	1515	1486	750	535	177	563
1987	8792	4571	6373	2152	837	761	358	255	353
1988	8553	6927	3323	3908	1105	393	329	155	263
1989	12468	6736	5031	2034	2001	517	169	141	179
1990	13072	9836	4916	3115	1061	957	228	75	141
1991	8109	10295	7142	3006	1592	496	411	98	93
1992	6998	6415	7581	4519	1624	794	229	190	88
1993	6673	5432	4454	4158	1938	615	268	77	94
1994	4492	5123	3644	2246	1557	625	172	75	48
1995	2781	3513	3640	2114	1055	658	239	66	47
1996	3520	2182	2522	2166	1034	468	266	96	46
1997	4596	2789	1614	1613	1190	526	222	126	67
1998	4630	3682	2136	1124	1017	714	301	127	111
1999	6231	3652	2869	1593	775	659	412	174	137
2000	2670	4839	2787	2058	1022	455	329	206	155
2001	2332	2081	3710	2017	1342	614	235	169	186
2002	2506	1816	1594	2681	1312	803	315	120	182
2003	2458	1977	1415	1189	1848	850	463	182	175
2004	2296	1916	1516	1025	777	1112	439	240	184
2005	3841	1812	1494	1132	708	504	645	255	246
2006	4946	3041	1419	1124	794	469	302	385	299
2007	4047	3967	2422	1103	837	571	317	204	462
2008	5053	3270	3190	1918	849	630	412	229	481
2009	5672	4084	2632	2529	1480	641	457	299	515
2010	5898	4574	3277	2075	1932	1102	456	325	579
2011	4006	4774	3688	2607	1610	1471	810	335	664

Table B75. Results of the retrospective analysis.

Year	2004	2005	2006	2007	2008	2009	2010	Mohn's rho
Ffull	-0.10	-0.24	-0.20	-0.17	-0.12	-0.05	-0.03	-0.13
SSB	0.11	0.28	0.22	0.22	0.14	0.06	0.03	0.15
Recruitment	1.56	0.76	1.29	-0.04	0.43	0.26	0.21	0.64

Table B76. Analysis of the probability of falling below twenty percent Bzero using long-term projections under different recruitment assumptions.

				fraction of draws below 0.2*SSB0		
steepness	SSB0	0.2*SSB0	SSBmsy	F35%	F40%	F that results in ~5% draws below 0.2*SSB0
0.6	139,200	27,840	51,300	26	7	0.19
0.7	128,100	25,620	42,960	10	2	0.22
0.8	119,200	23,840	36,940	4	1	between 0.24-0.25
emp.cdf (hockey stick)	81,700	16,340	28,450 (F35) or 32,400 (F40)	0	0	between 0.35-0.36

Table B77. Comparison of the existing biological reference points with the new biological reference points.

	GARM III	SARC 56
*F*msy proxy (F40%)	0.125 (on age 6)	0.2 (on age 6)
SSB/R	5.94	6.19
Mean R	8.0 million	5.5 million
SSBMSY proxy	56,300 mt	32,400 mt
F pattern	Domed	Asymptotic at age 6
MSY	5,800 mt	5,630 mt

Table B78**.** Short term projections of total fishery yield and spawning stock biomass for Gulf of Maine-Georges Bank white hake based on a harvest scenario of fishing at F_{MSY} between 2013 and 2016. Catch in 2012 has been estimated at 2,900 mt.

Long Time Series of Recruitment (1963-2009)

Year	**Catch**	**5%**	**95%**	**SSB**	**5%**	**95%**	**F**
2012	2.900			28.886	24.659	33.166	0.12
2013	5.462	4.697	6.309	31.669	27.017	36.719	0.20
2014	5.594	4.797	6.482	32.108	27.573	37.385	0.20
2015	5.587	4.849	6.484	31.843	27.677	36.930	0.20
2016	5.516	4.779	6.428	31.815	27.516	37.213	0.20

Short Time Series of Recruitment (1995-2009)

Year	**Catch**	**5%**	**95%**	**SSB**	**5%**	**95%**	**F**
2012	2.900			28.886	24.659	33.166	0.12
2013	5.457	4.642	6.302	31.654	26.976	36.708	0.20
2014	5.574	4.774	6.459	32.010	27.440	37.284	0.20
2015	5.504	4.777	6.393	31.276	27.238	36.238	0.20
2016	5.287	4.616	6.112	30.178	26.448	34.627	0.20

Table B79**.** Short term projections of total fishery yield and spawning stock biomass for Gulf of Maine-Georges Bank white hake based on a harvest scenario of fishing at 75% F_{MSY} between 2013 and 2016. Catch in 2012 has been estimated at 2,900 mt.

Long Time Series of Recruitment (1963-2009)

Year	**Catch**	**5%**	**95%**	**SSB**	**5%**	**95%**	**F**
2012	2.900			28.886	24.659	33.166	0.12
2013	4.181	3.313	5.205	31.999	27.297	37.095	0.15
2014	4.450	3.566	5.567	33.656	28.911	39.175	0.15
2015	4.595	3.704	5.742	34.473	29.952	39.951	0.15
2016	4.668	3.803	5.830	35.371	30.641	41.248	0.15

Short Time Series of Recruitment (1995-2009)

Year	**Catch**	**5%**	**95%**	**SSB**	**5%**	**95%**	**F**
2012	2.900			28.886	24.659	33.166	0.12
2013	4.177	3.552	4.823	31.986	27.255	37.085	0.15
2014	4.435	3.796	5.137	33.559	28.765	39.087	0.15
2015	4.532	3.929	5.266	33.893	29.505	39.269	0.15
2016	4.490	3.919	5.193	33.683	29.521	38.663	0.15

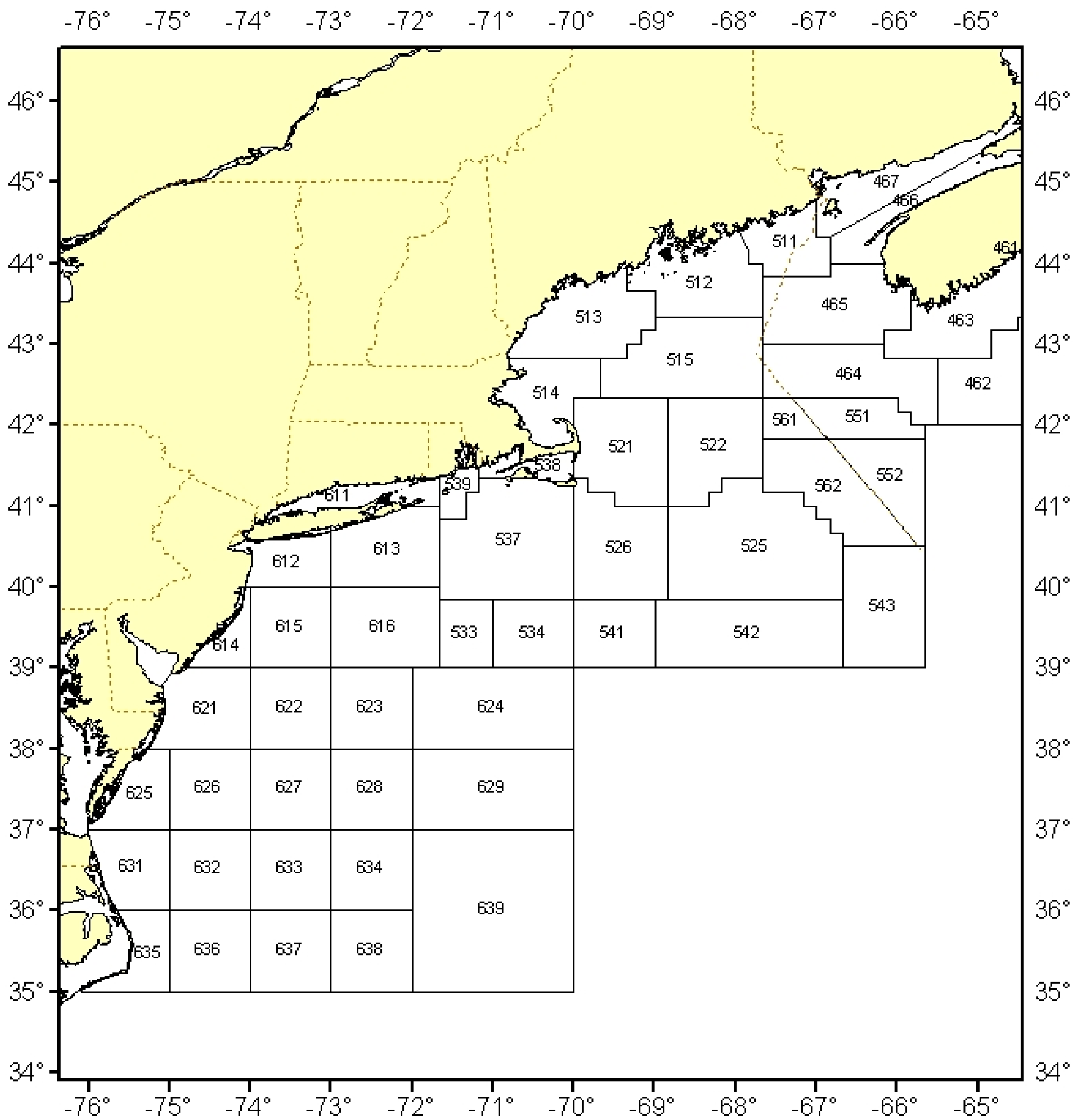


Figure B1. Statistical areas used for reporting United States commercial landings.

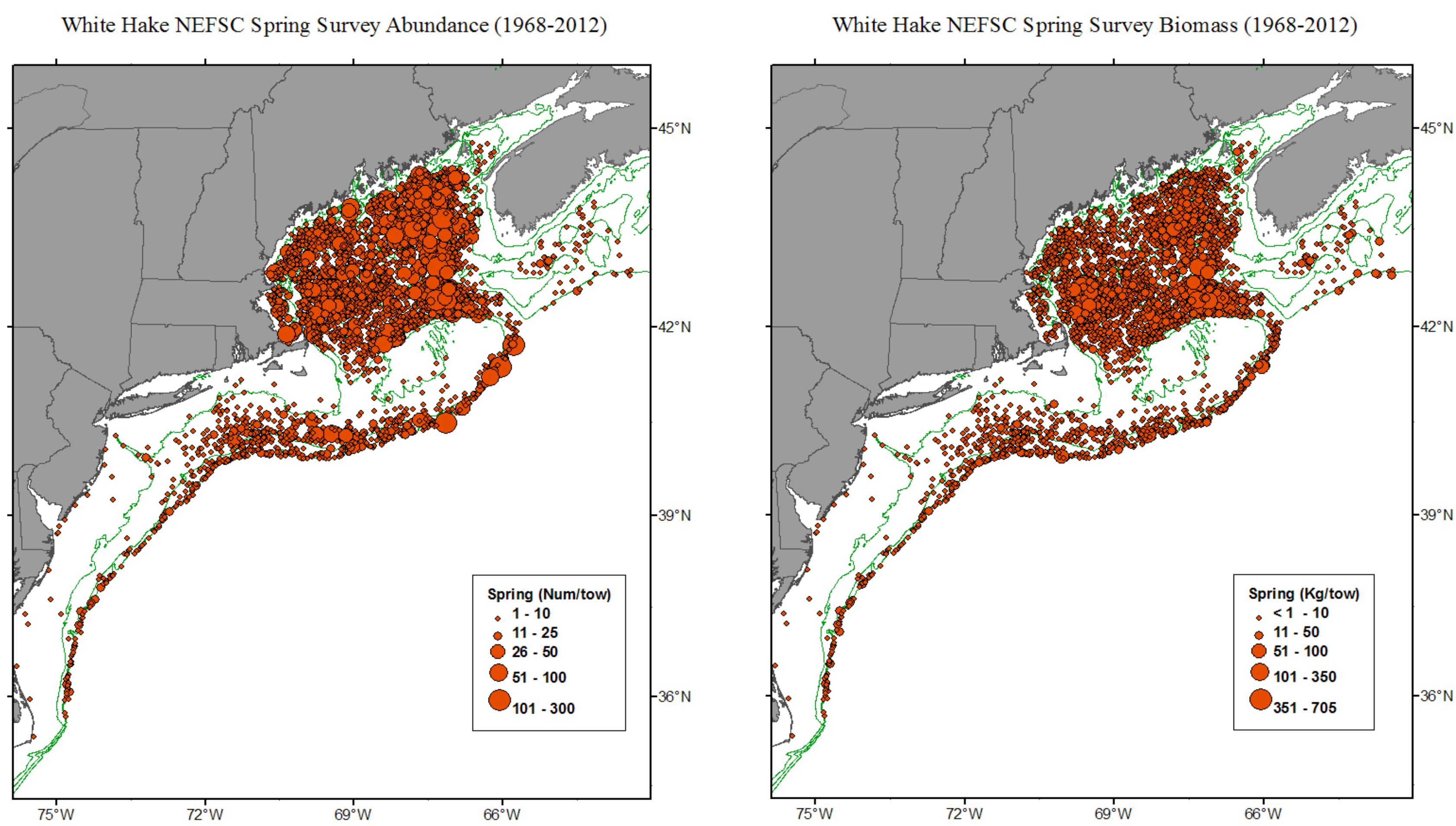


Figure B2. Distribution of white hake from the NEFSC spring survey in number/tow (left panel) and weight/tow (right panel) from 1968-2012.

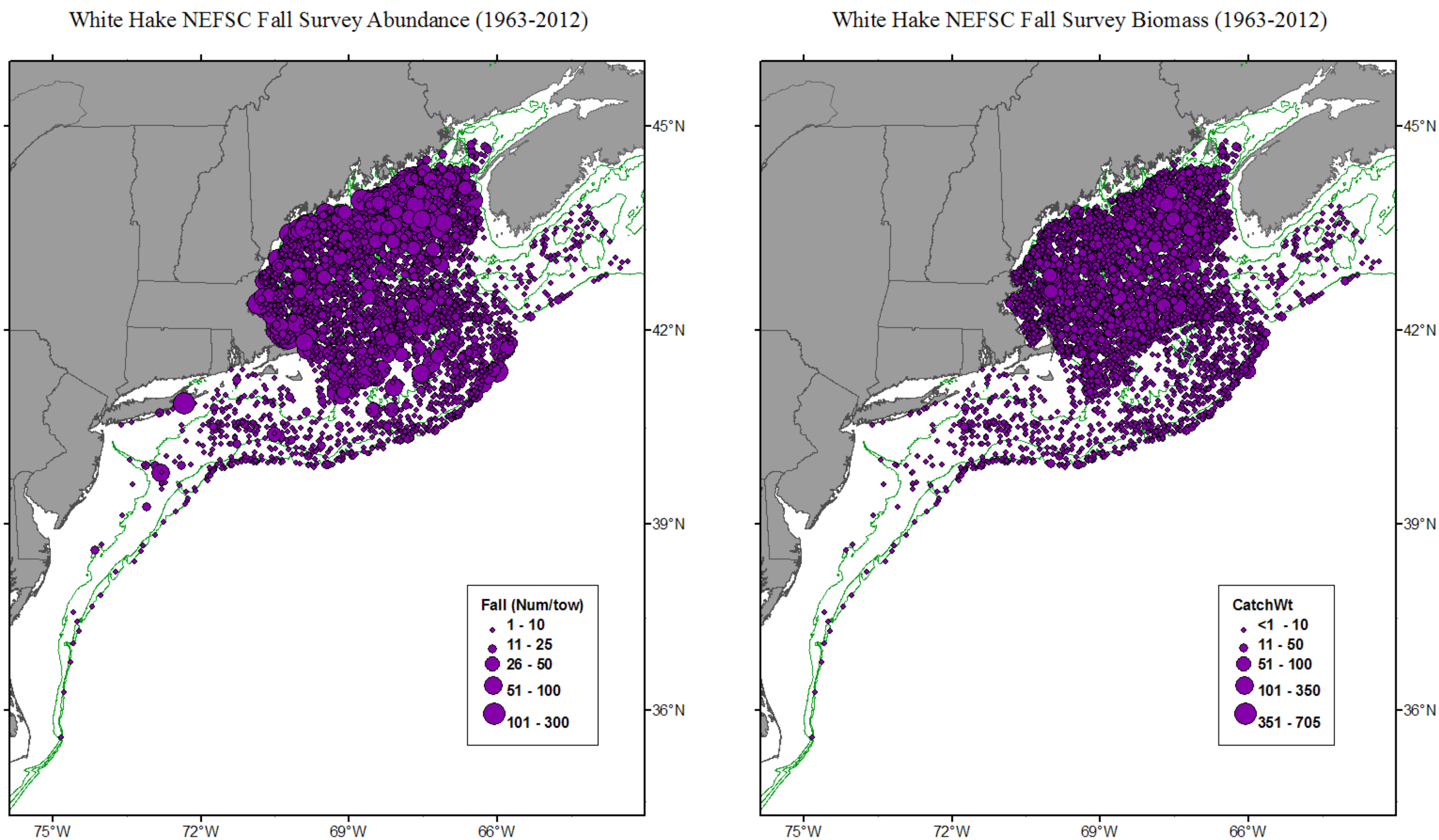


Figure B3a. Distribution of white hake from the NEFSC autumn survey in number/tow (left panel) and weight/tow (right panel) from 1963-2012.

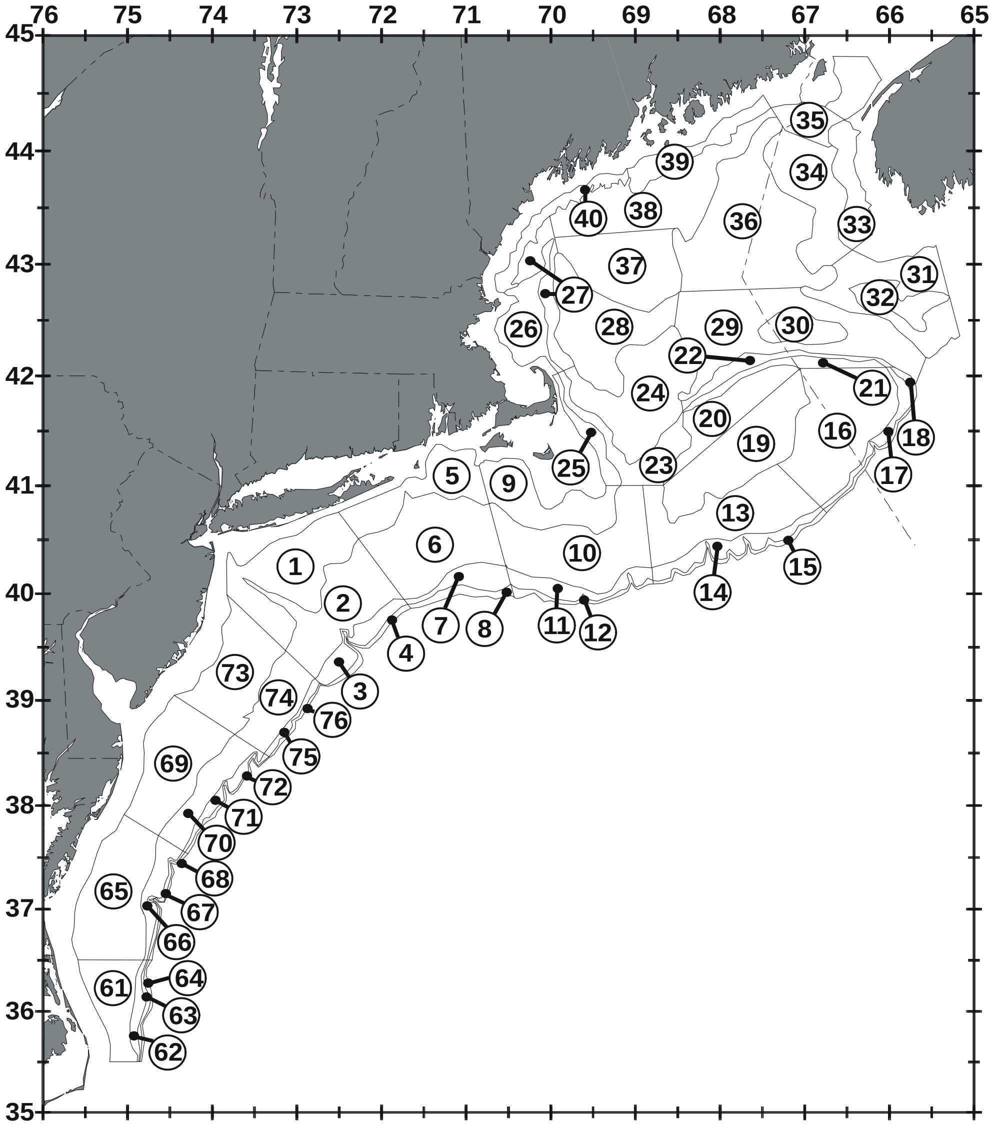
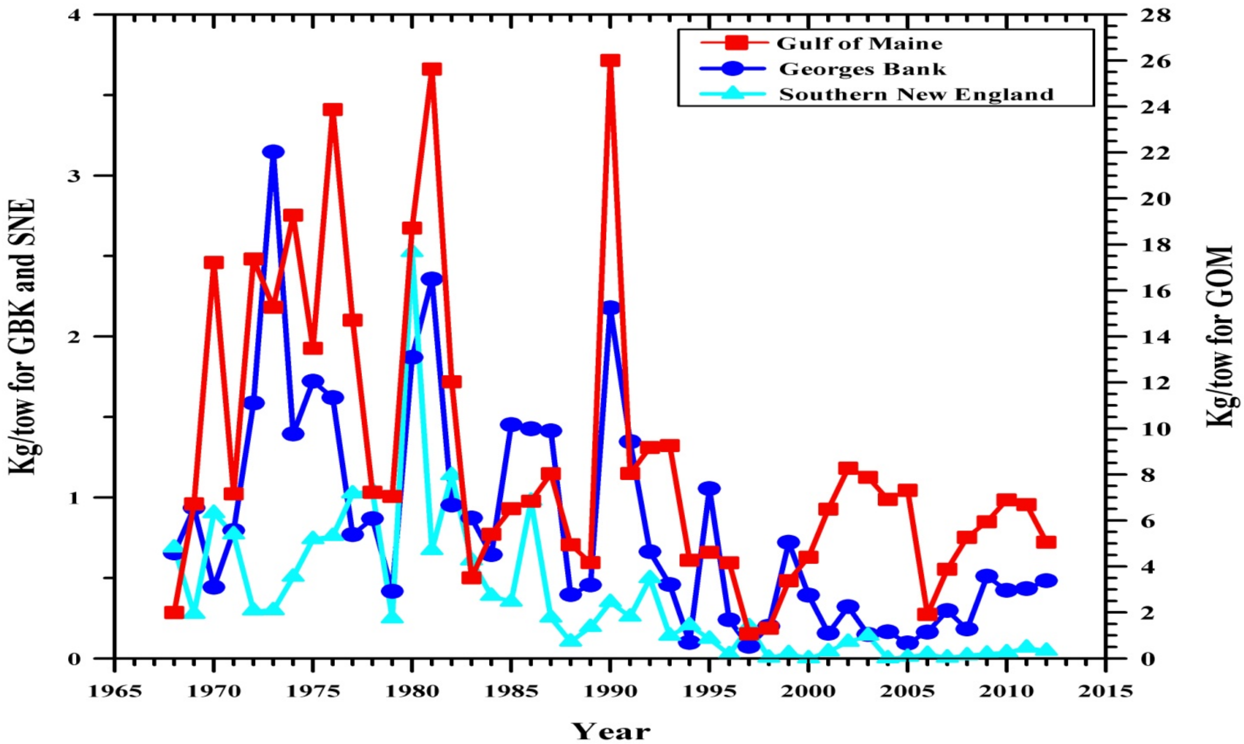


Figure B4. Offshore survey strata for the NEFSC survey.



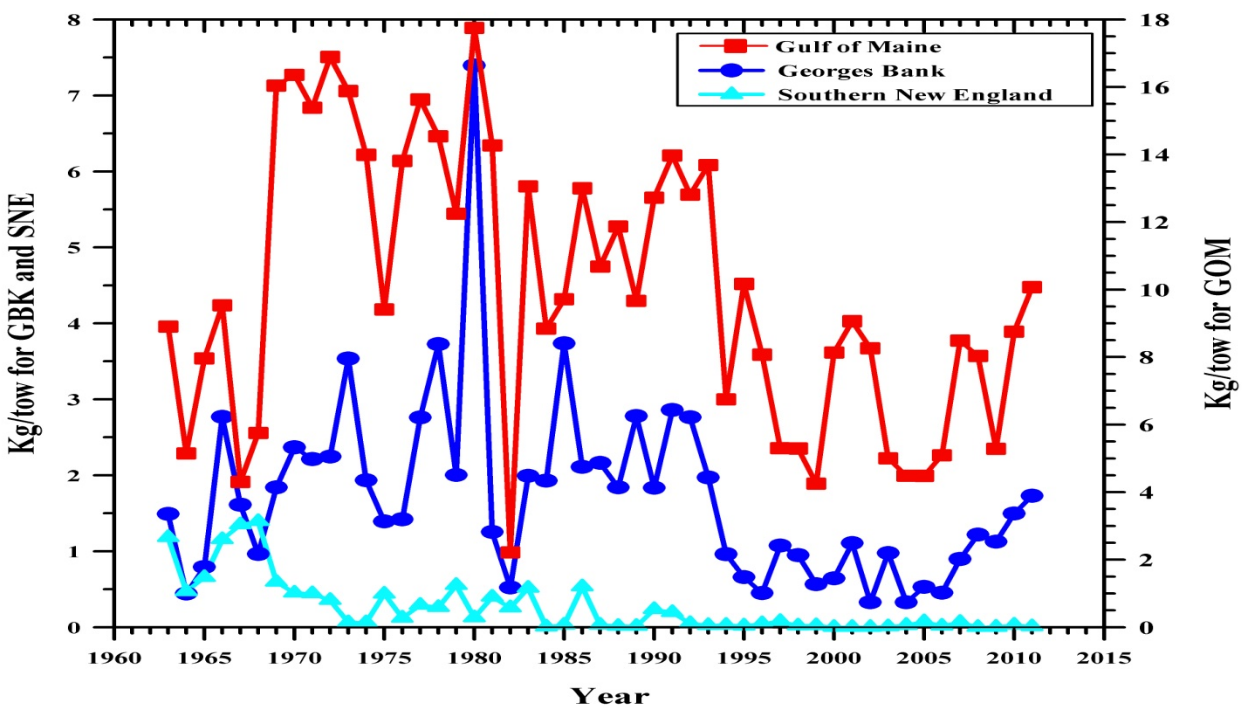


Figure B5. Biomass indices of white hake from the spring (top) and fall (bottom) surveys from Gulf of Maine (offshore strata 26-30, 36-40, GOM), Georges Bank (offshore strata 13-25, GB) and Southern New England (offshore strata 1-12,SNE).

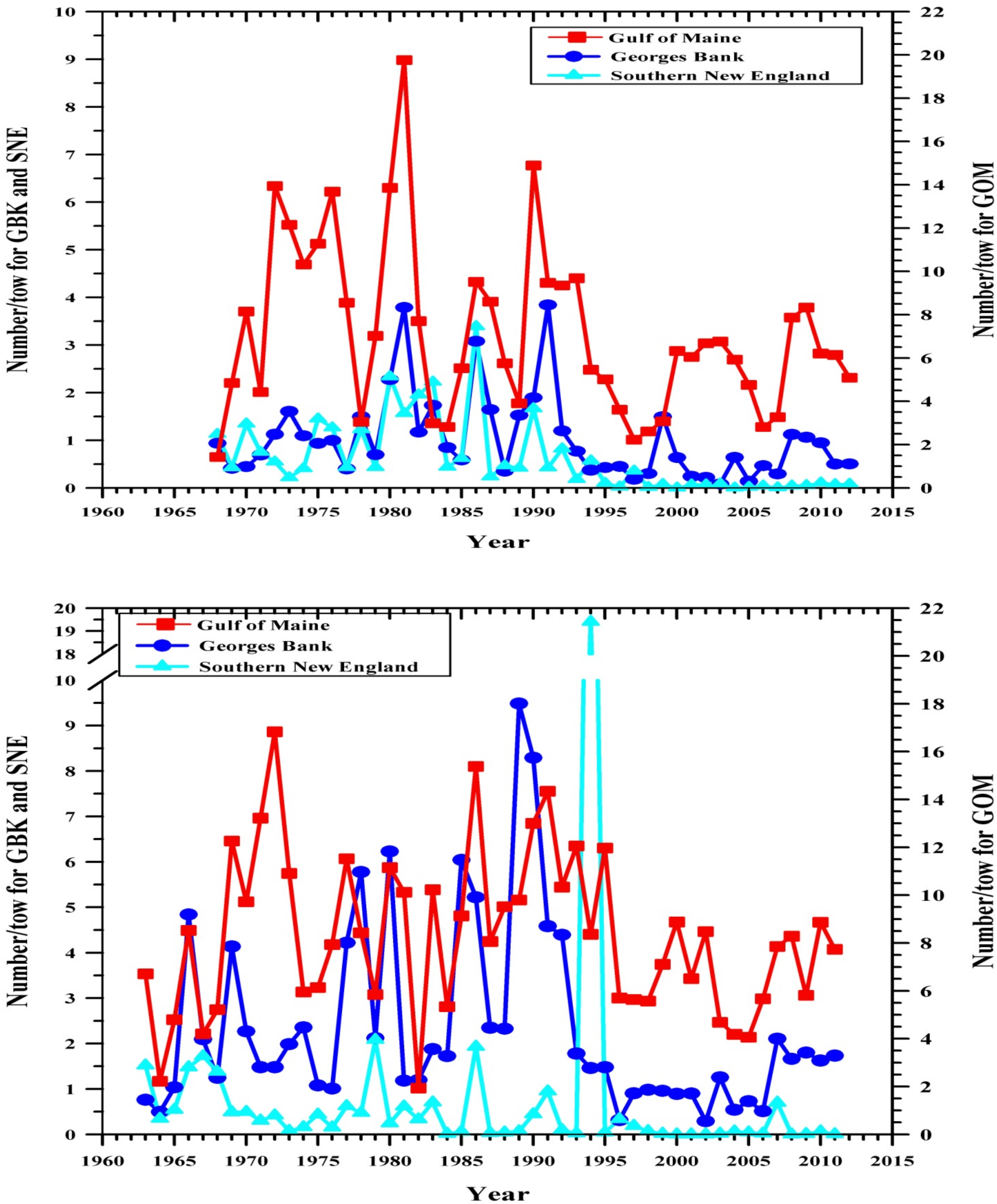
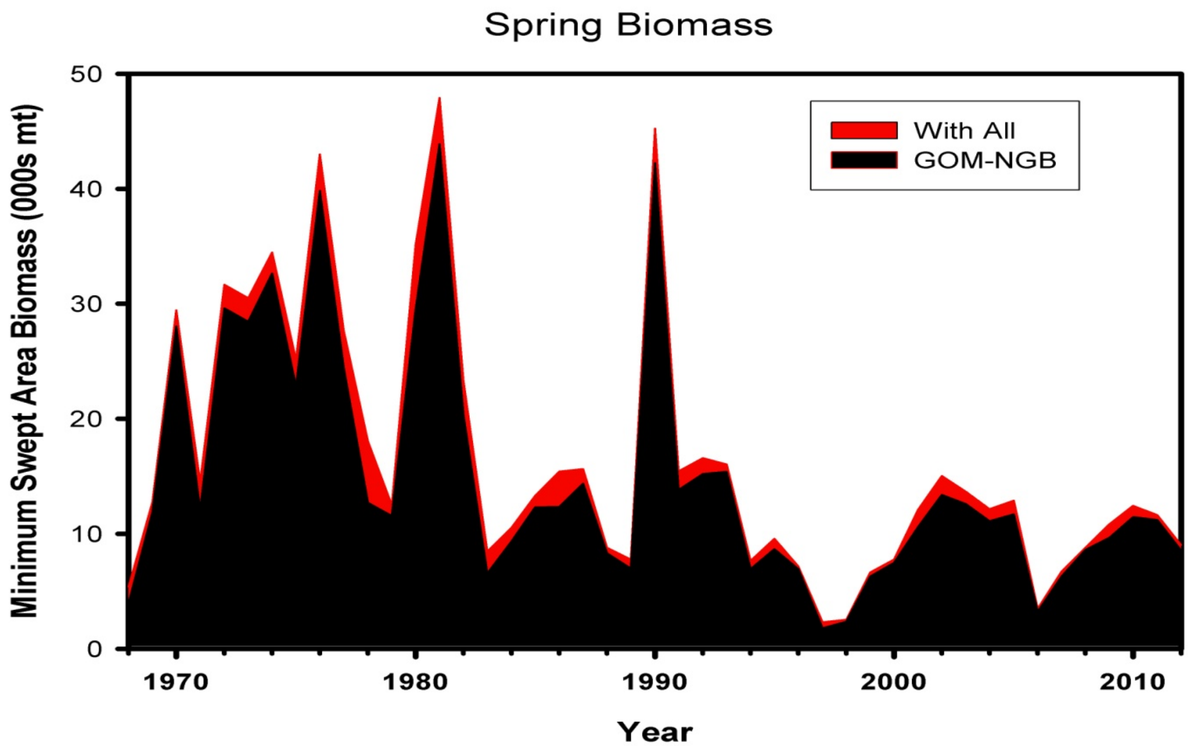


Figure B6. Abundance indices of white hake from the spring (top) and fall (bottom) surveys from Gulf of Maine (offshore strata 26-30, 36-40, GOM), Georges Bank (offshore strata 13-25, GB) and Southern New England (offshore strata 1-12,SNE).



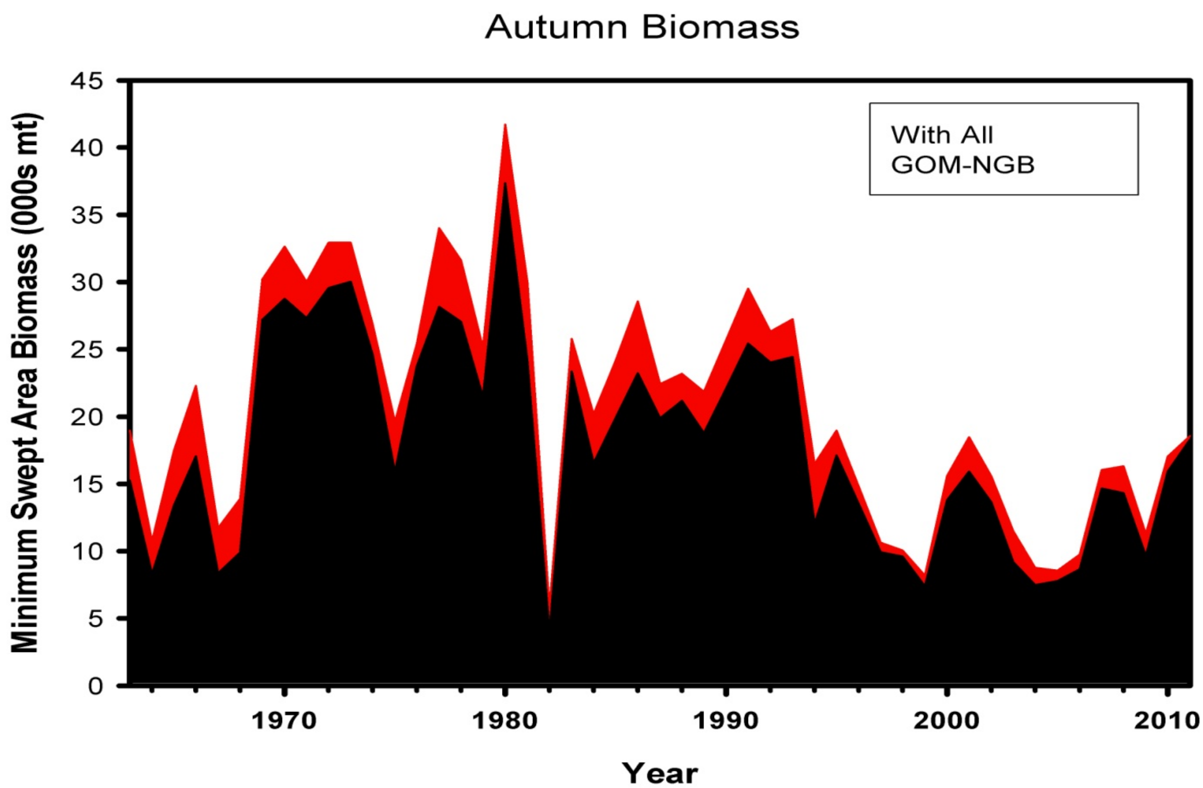
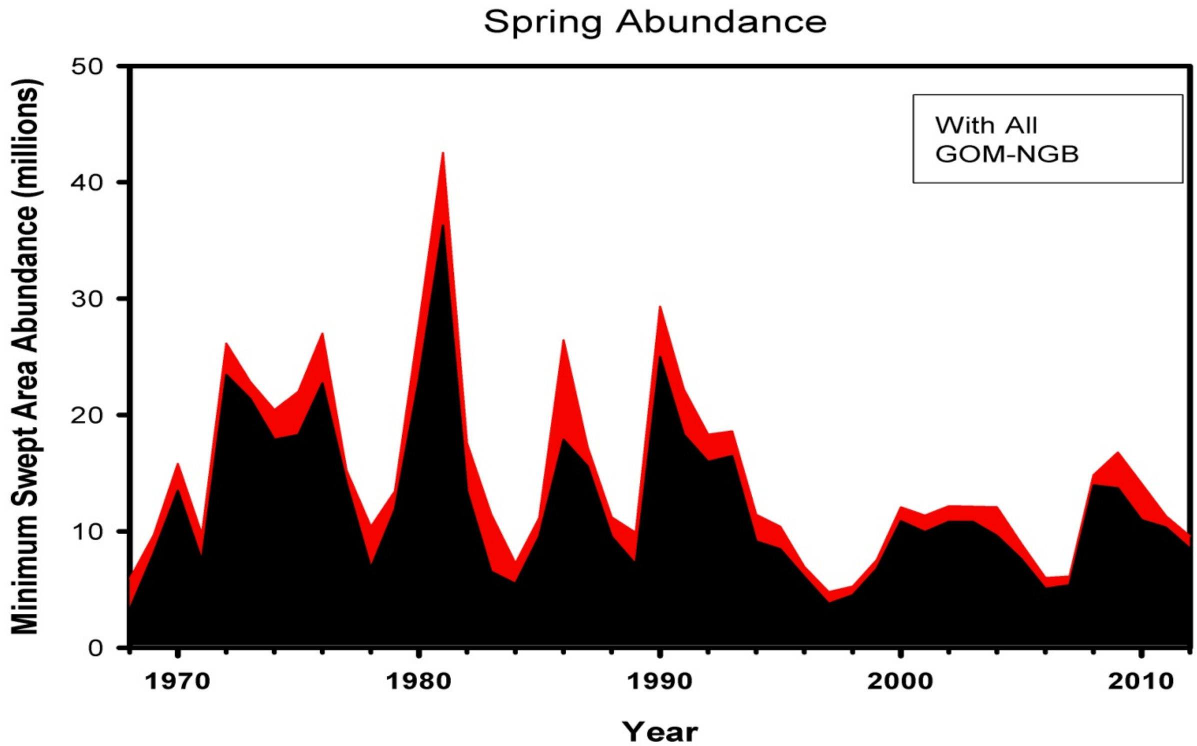


Figure B7. Swept-area biomass of white hake from the spring (top) and fall (bottom) surveys using the current stock definition (offshore strata 21-30, 33-40) and all strata (offshore strata 1-30, 33-40, 61-76, Inshore strata 1-66).



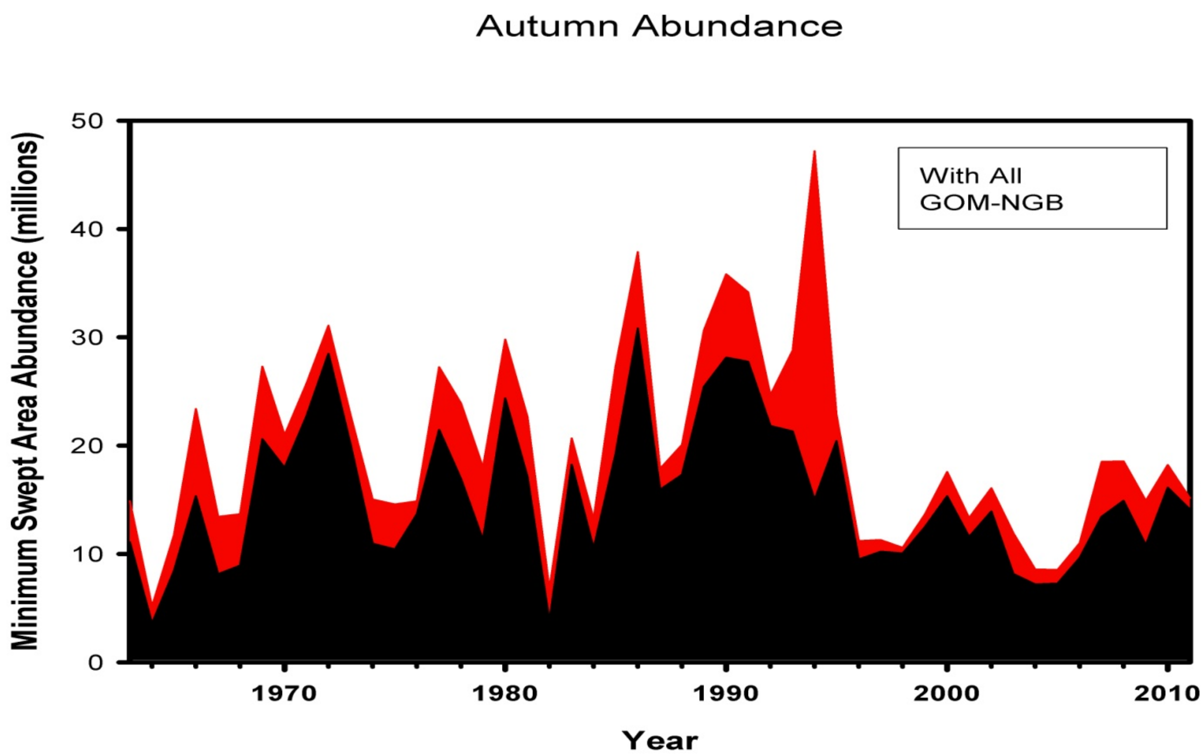
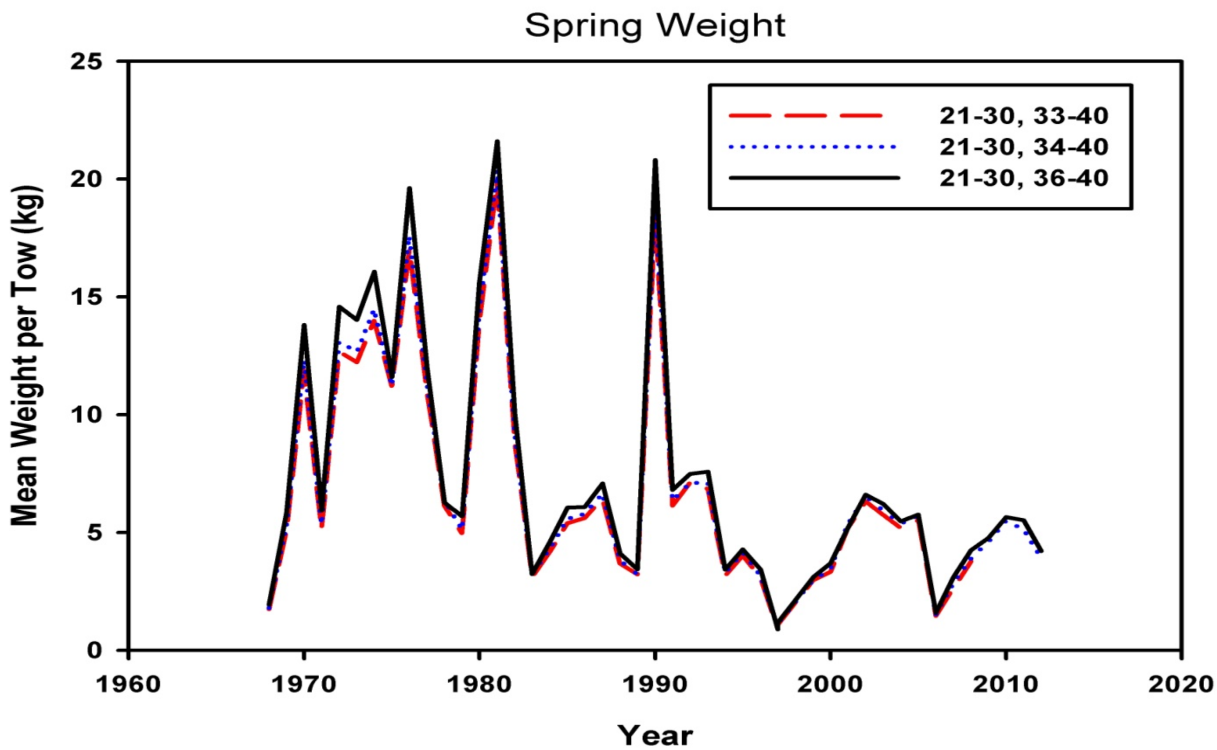


Figure B8. Swept-area abundance of white hake from the spring (top) and fall (bottom) surveys using the current stock definition (offshore strata 21-30, 33-40) and all strata offshore strata 1-30, 33-40, 61-76, Inshore strata 1-66).



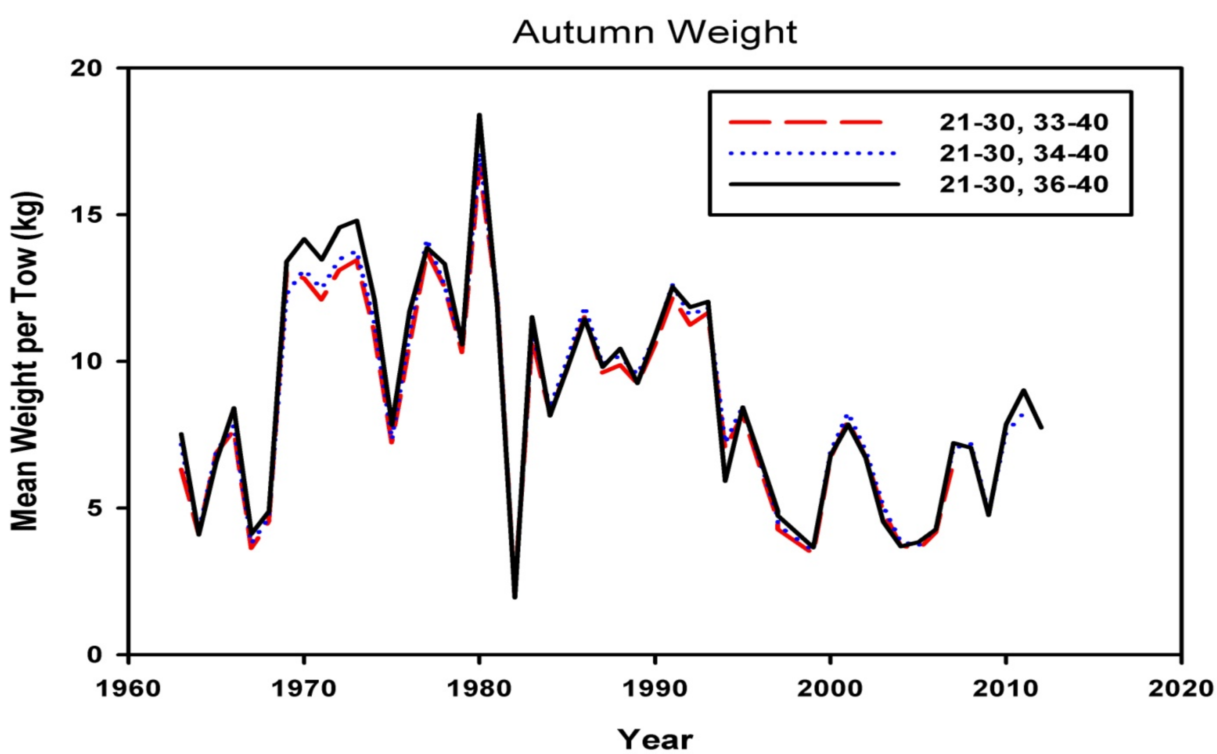


Figure B9. Biomass indices of white hake from the spring (top) and fall (bottom) surveys using the current stock definition (offshore strata 21-30, 33-40), dropping stratum 33 which is no longer sampled (offshore strata 21-30, 34-40) and no Scotian Shelf strata (offshore strata 21-30, 36-40).

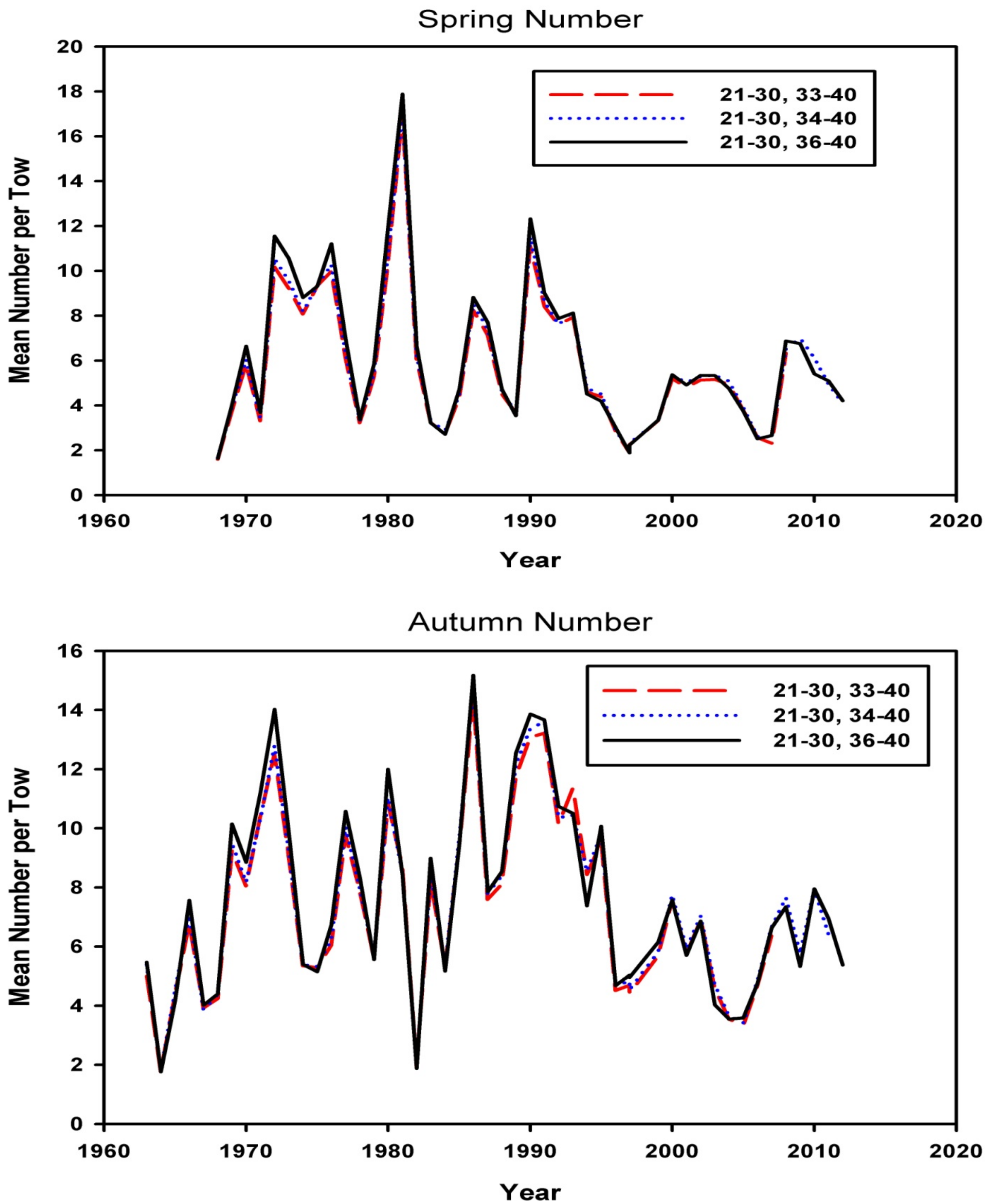


Figure B10. Abundance indices of white hake from the spring (top) and fall (bottom) surveys using the current stock definition (offshore strata 21-30, 33-40), dropping stratum 33 which is no longer sampled (offshore strata 21-30, 34-40) and no Scotian Shelf strata (offshore strata 21-30, 36-40).

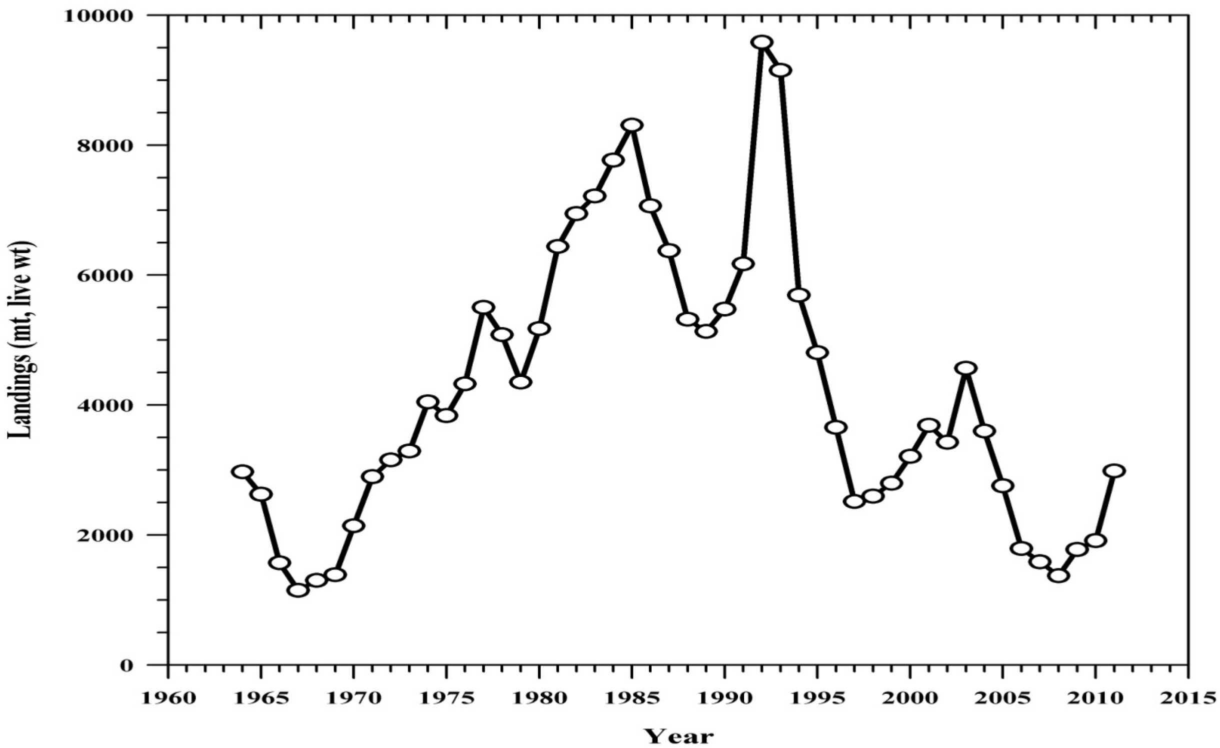


Figure B11. Total nominal commercial landings (mt, live weight) of white hake from 1964-2011.

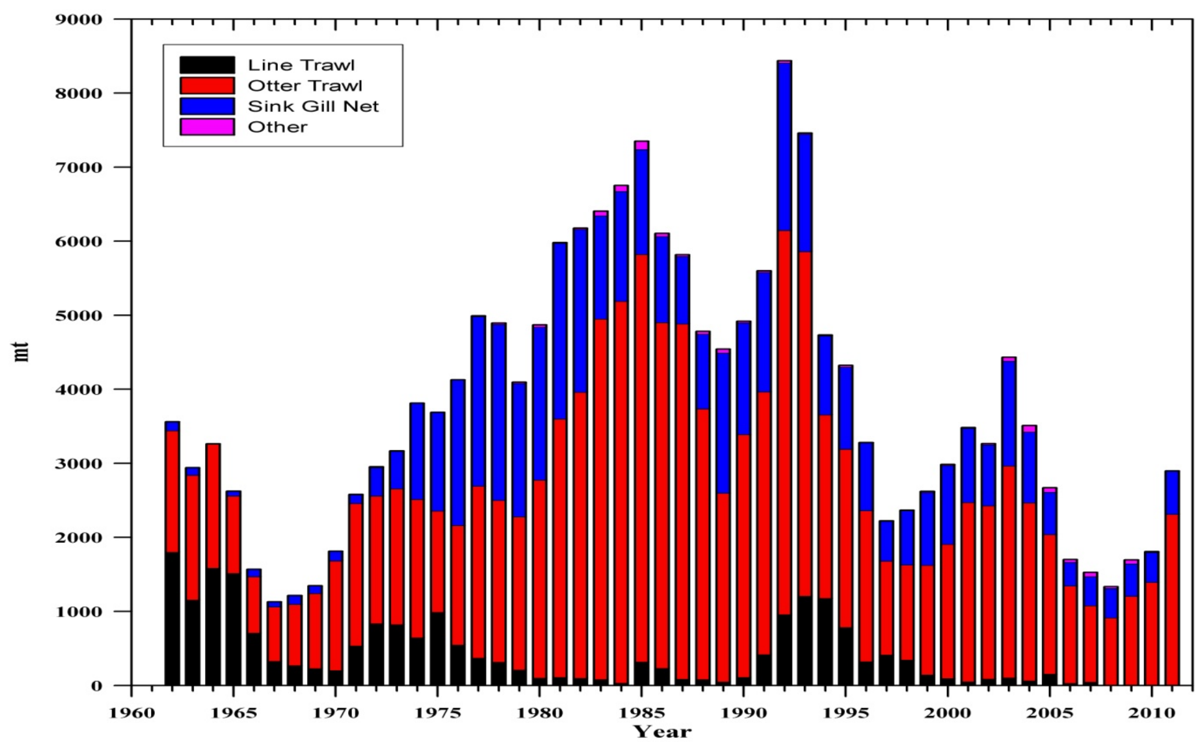


Figure B12. Nominal U.S. commercial landings (mt, live weight) of white hake by gear type from 1964-2011.

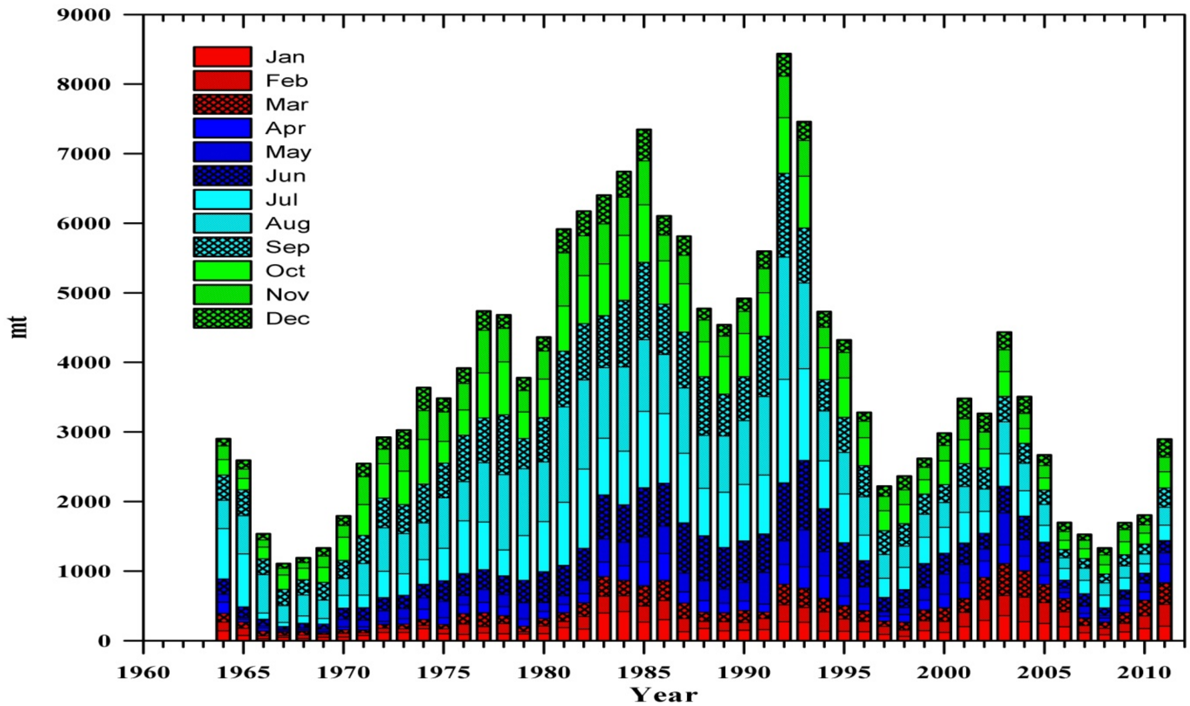


Figure B13. Nominal U.S. commercial landings (mt, live weight) of white hake by month from 1964-2011.

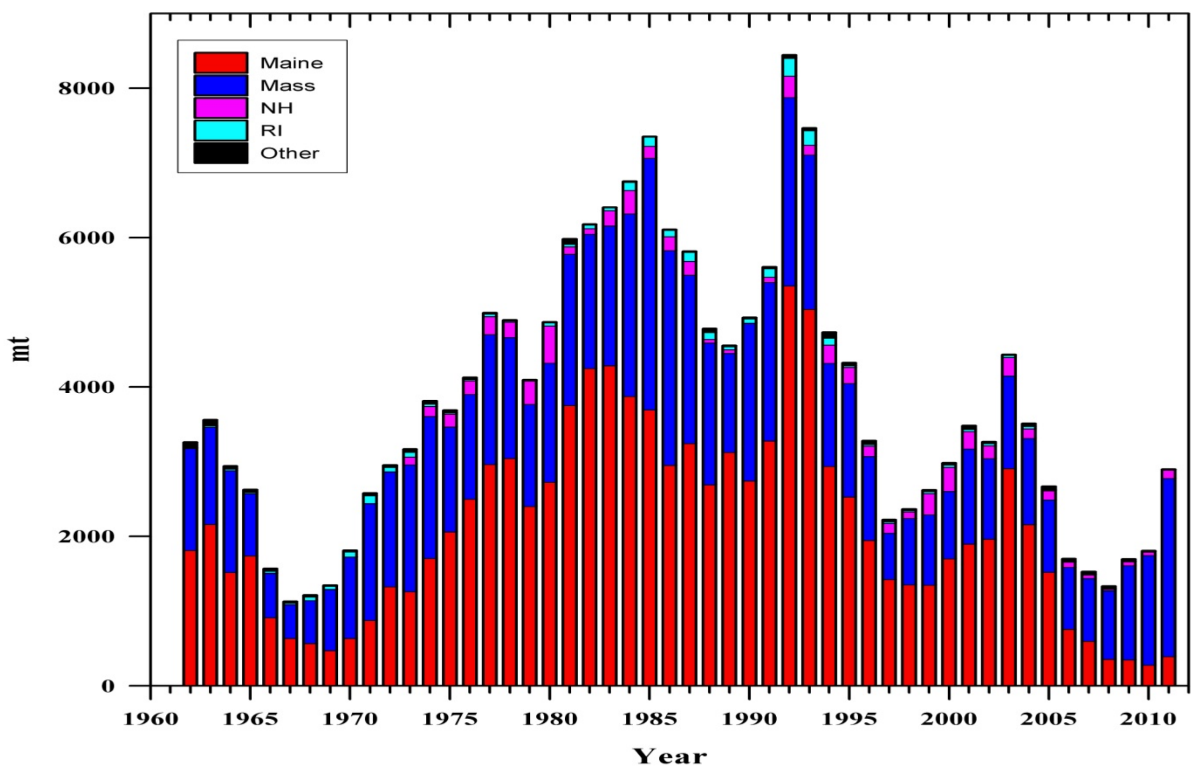


Figure B14. Nominal U.S. commercial landings (mt, live weight) of white hake by state from 1964-2011.

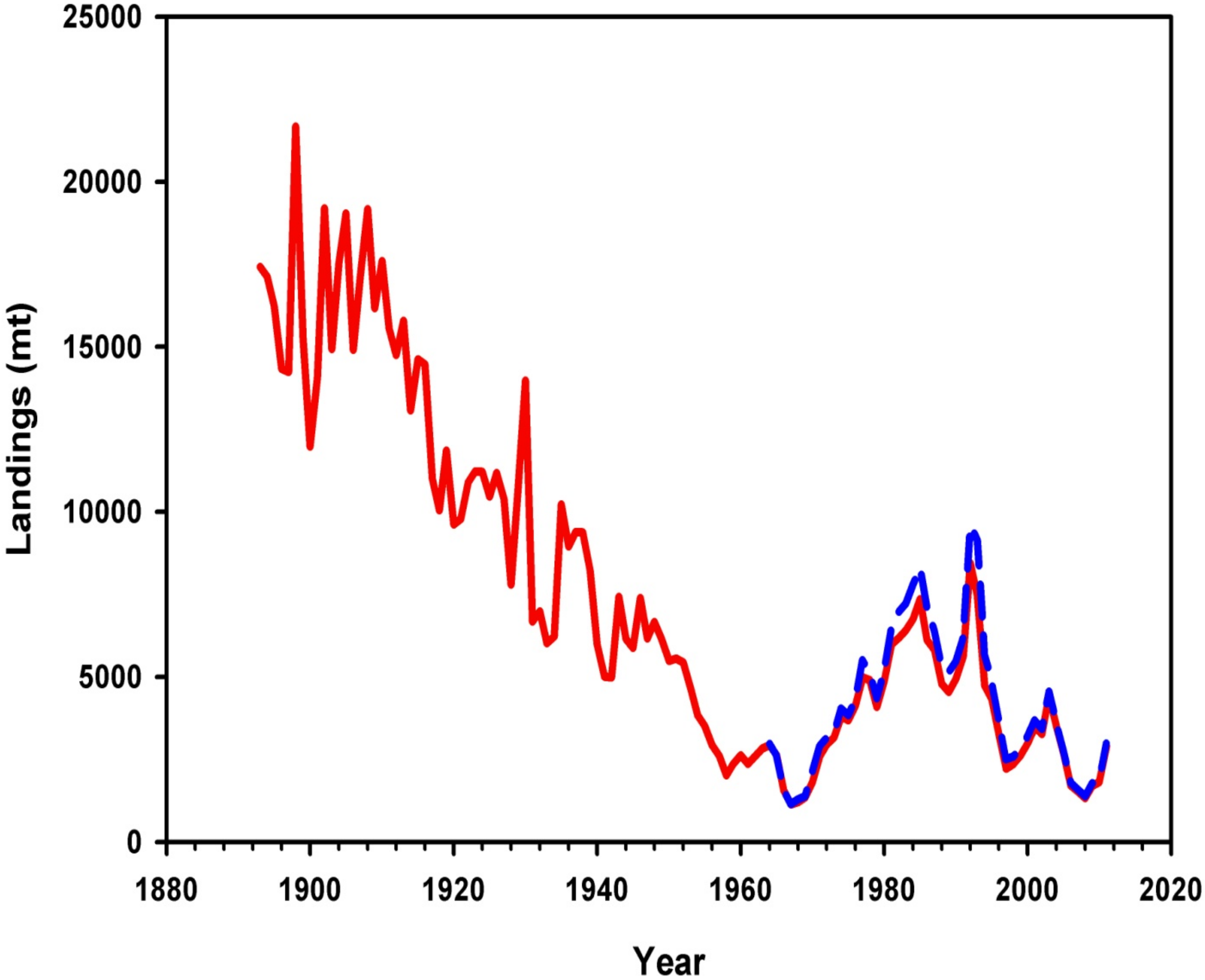
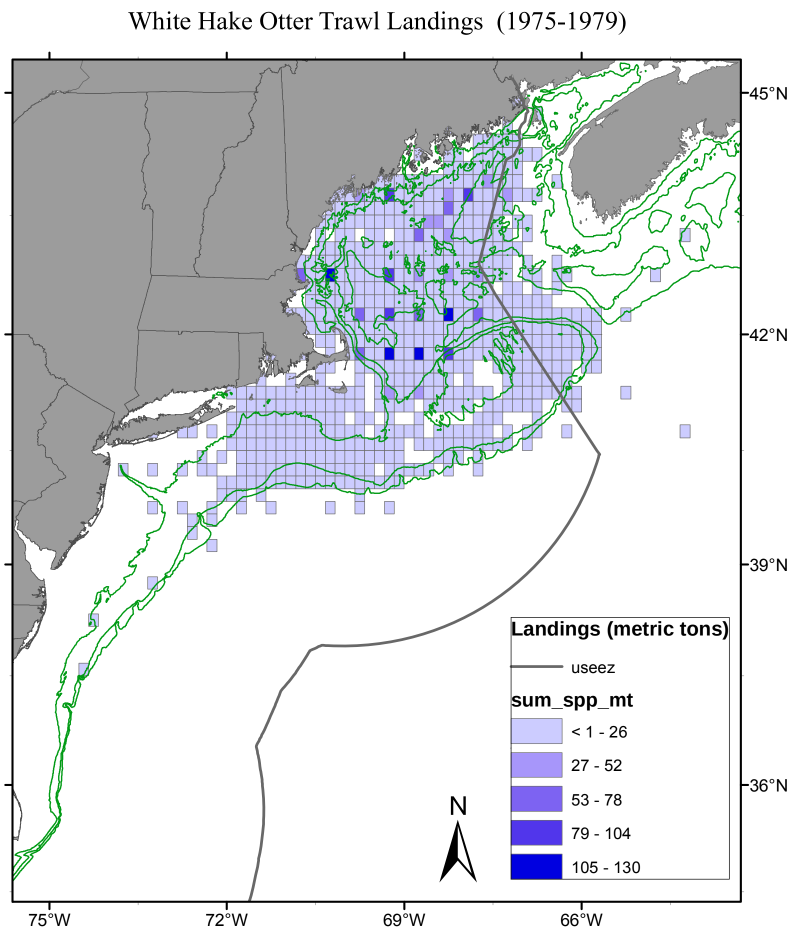


Figure B15. Total landings of white hake. The red line is US landings while the blue dashed line is the total landings including Canada and other countries.



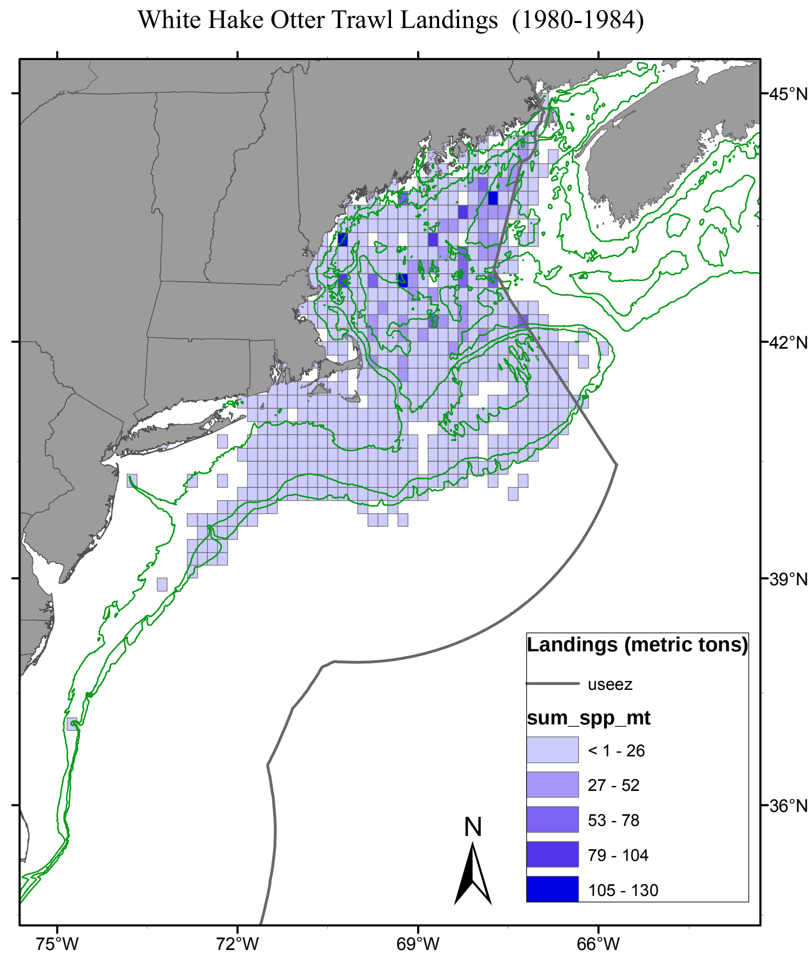
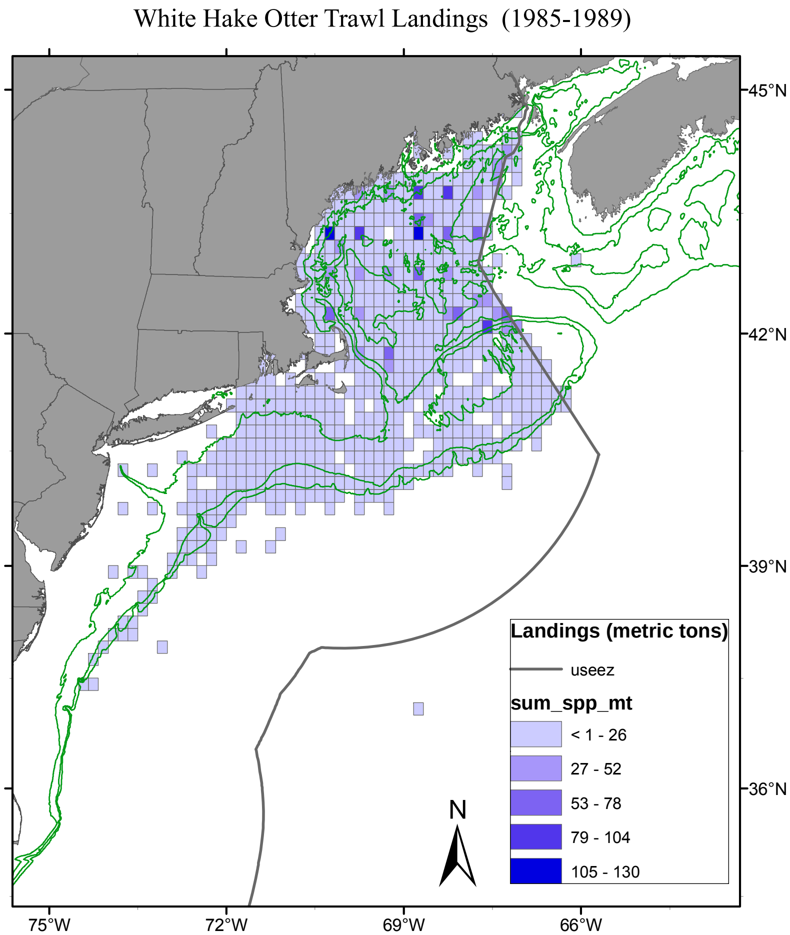


Figure B16. Landings of white hake from the otter trawl fishery from 1975-1979 and 1980-1984.



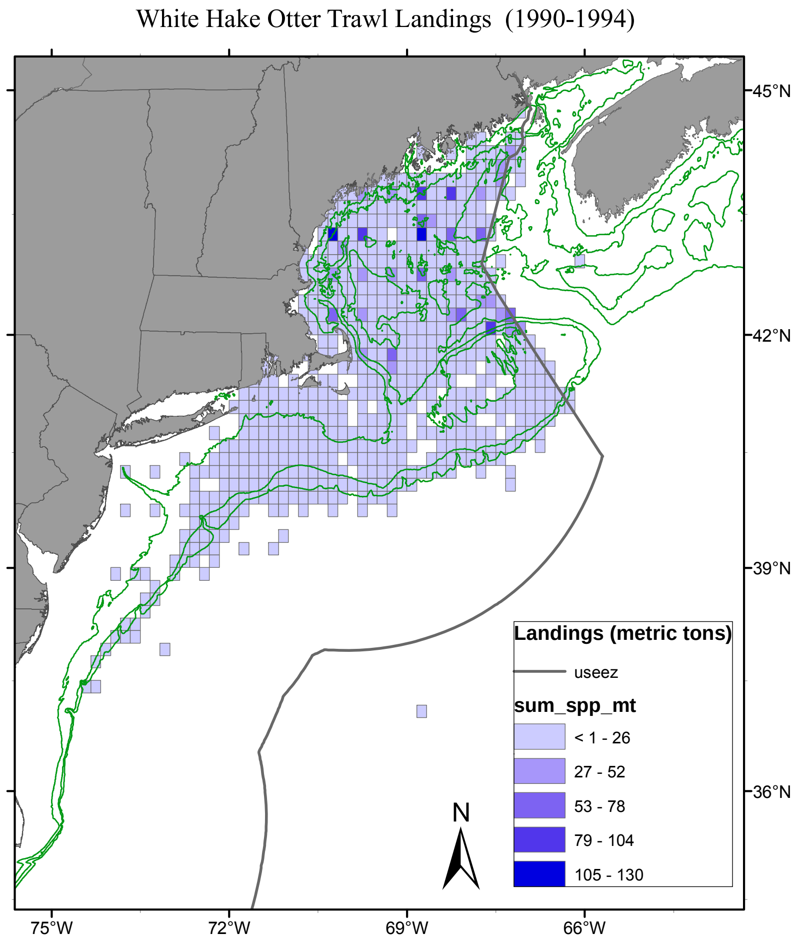
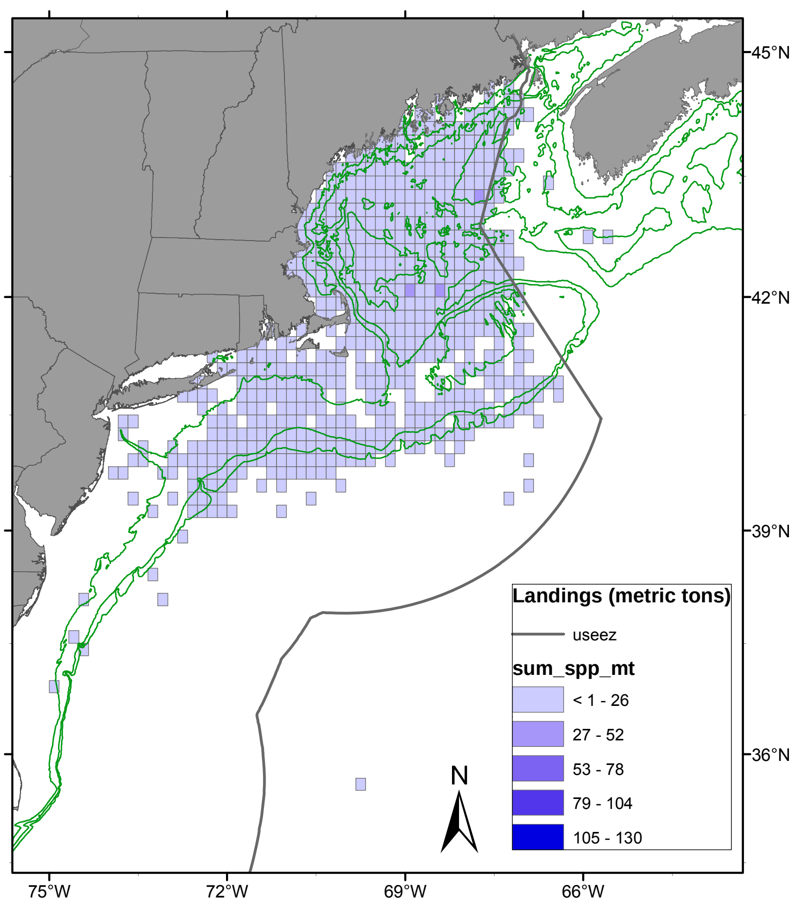


Figure B17. Landings of white hake from the otter trawl fishery from 1985-1989 and 1990-1994.

White Hake Otter Trawl Landings (1995-1999)



White Hake Otter Trawl Landings (2000-2004)

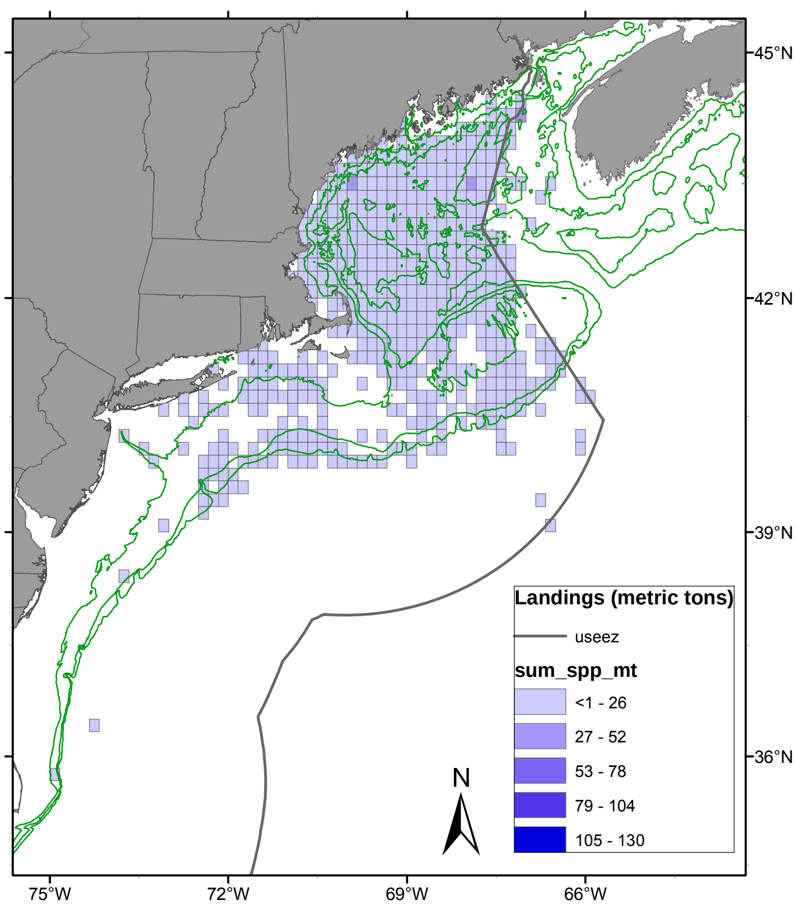
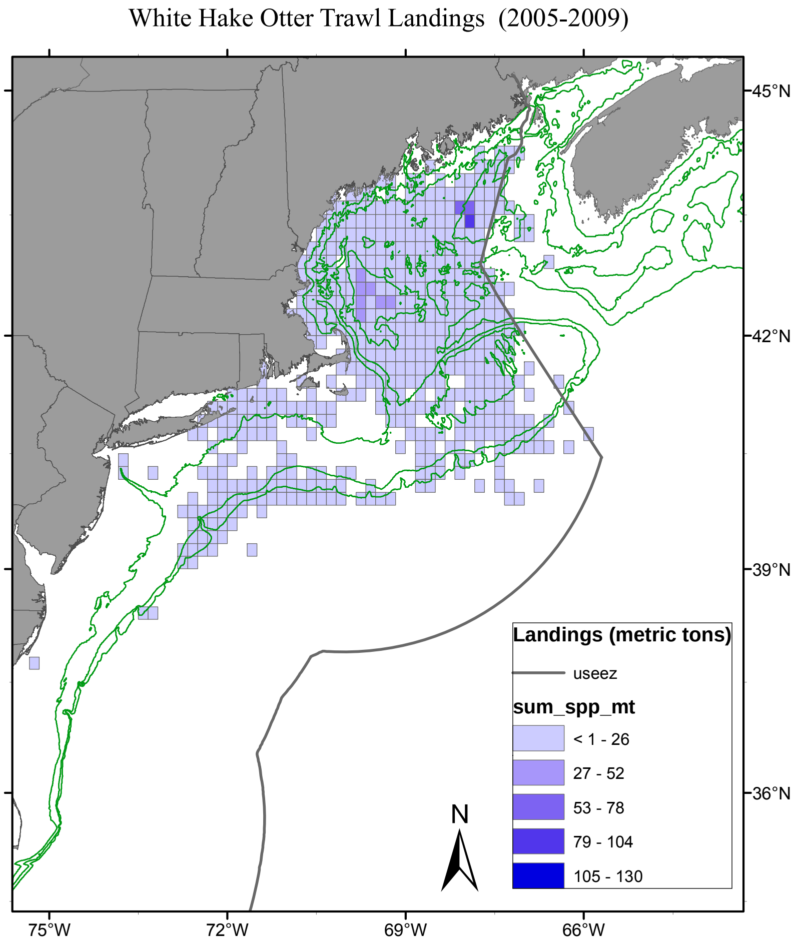


Figure B18. Landings of white hake from the otter trawl fishery from 1995-1999 and 2000-2004.



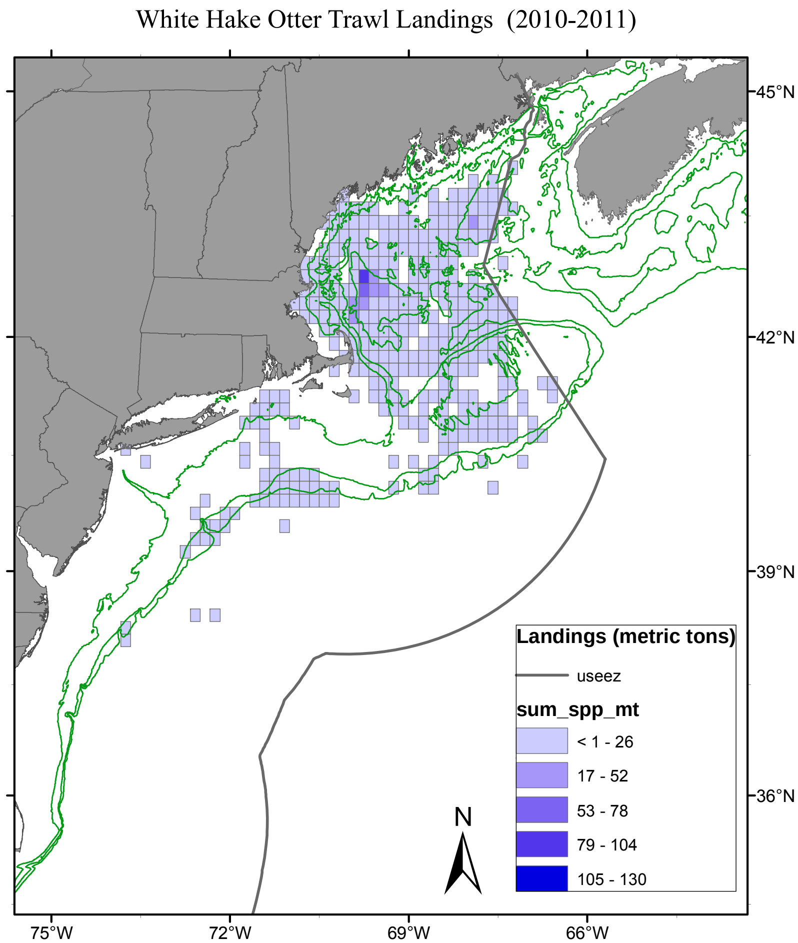
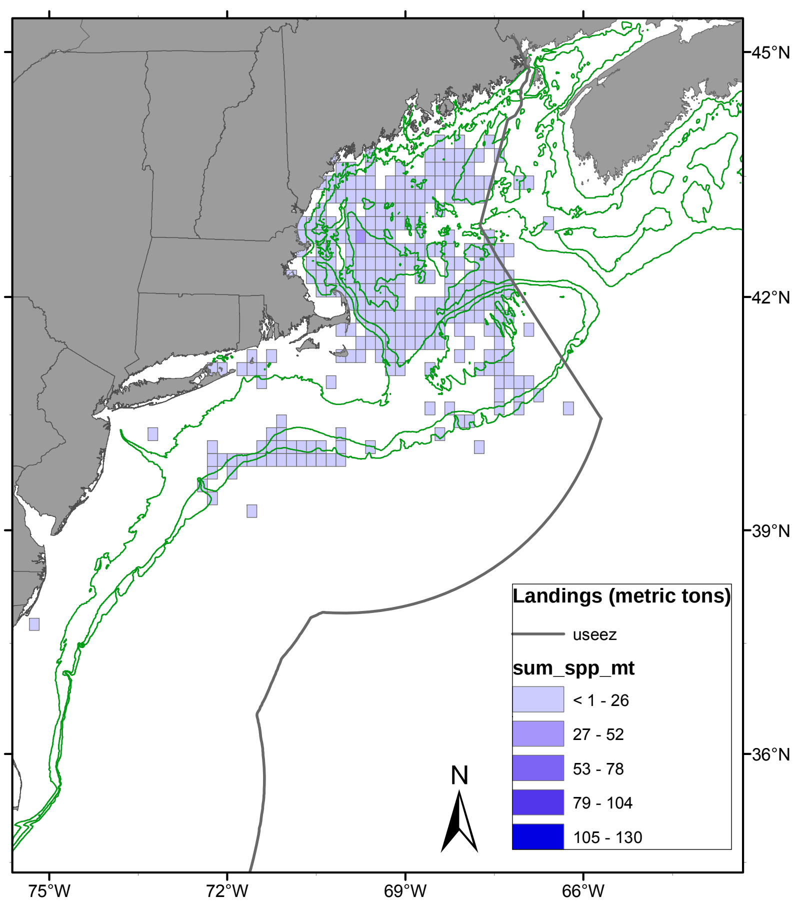


Figure B19. Landings of white hake from the otter trawl fishery from 2005-2009 and 2010-2011.

White Hake Otter Trawl Landings (2008)



White Hake Otter Trawl Landings (2009)

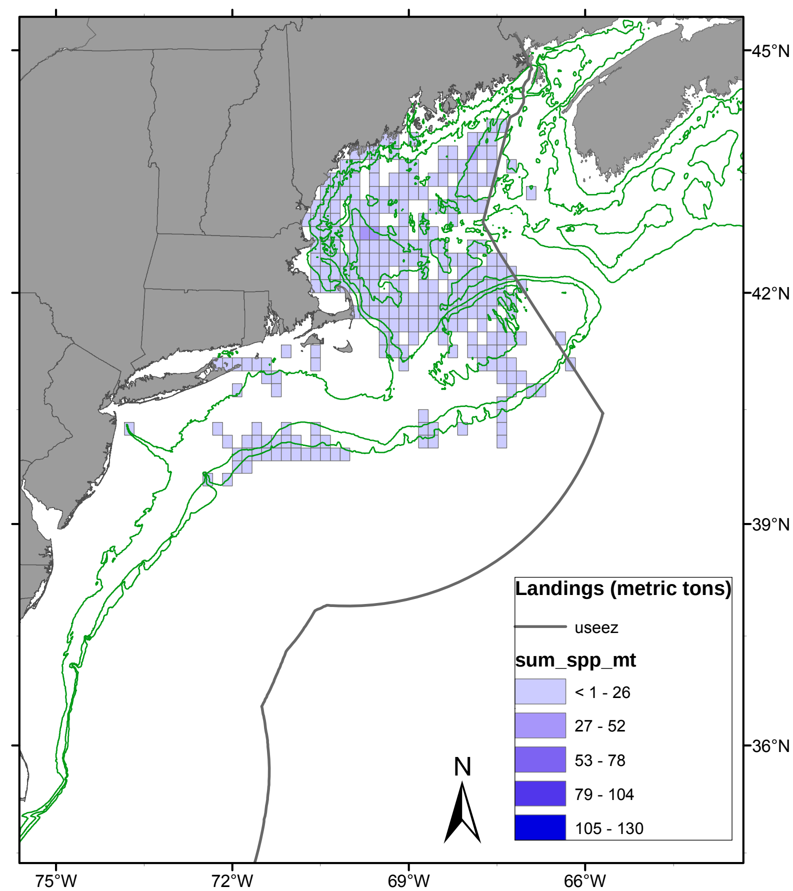
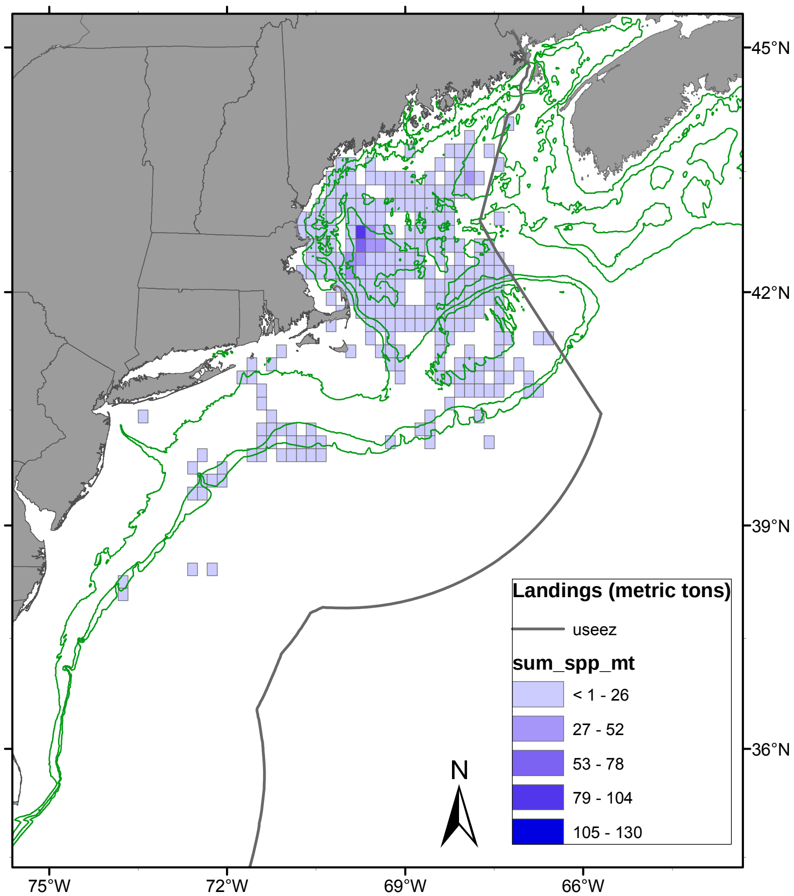


Figure B20a. Landings of white hake from the otter trawl fishery from 2008-2011.

White Hake Otter Trawl Landings (2010)



White Hake Otter Trawl Landings (2011)

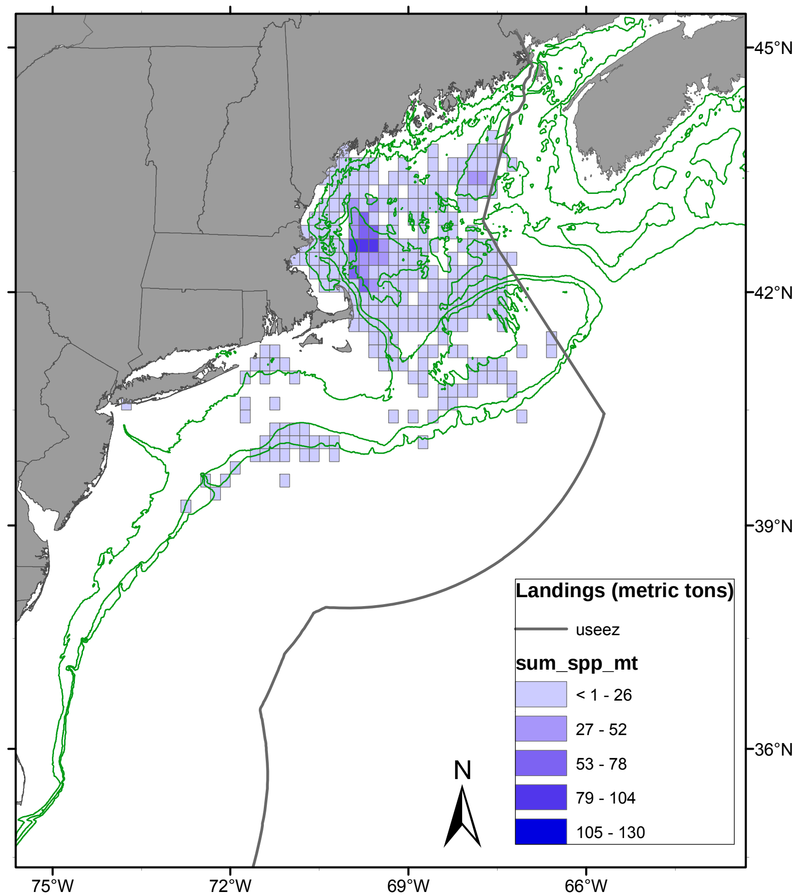
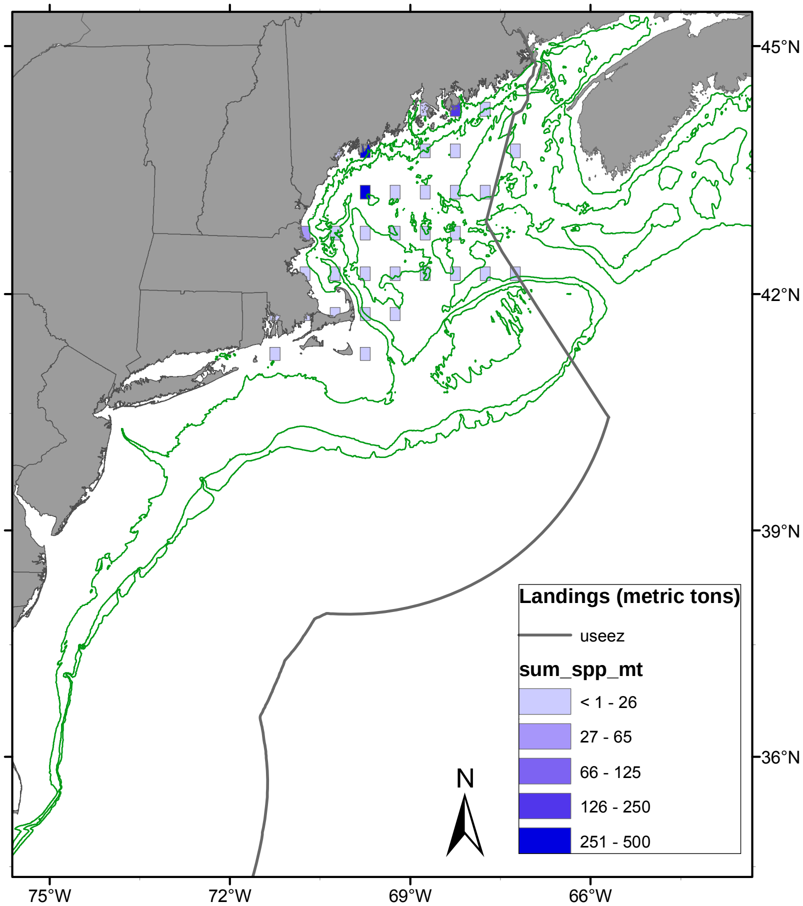


Figure B20b. Landings of white hake from the otter trawl fishery from 2008-2011.

White Hake Gillnet Landings (1975-1979)



White Hake Gillnet Landings (1980-1984)

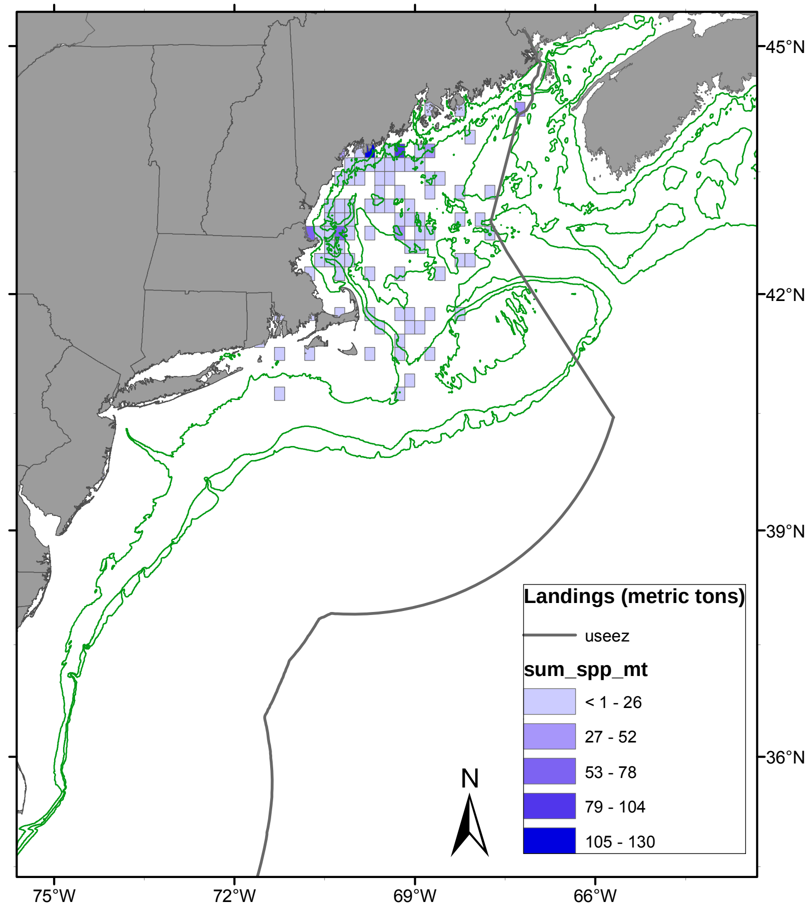
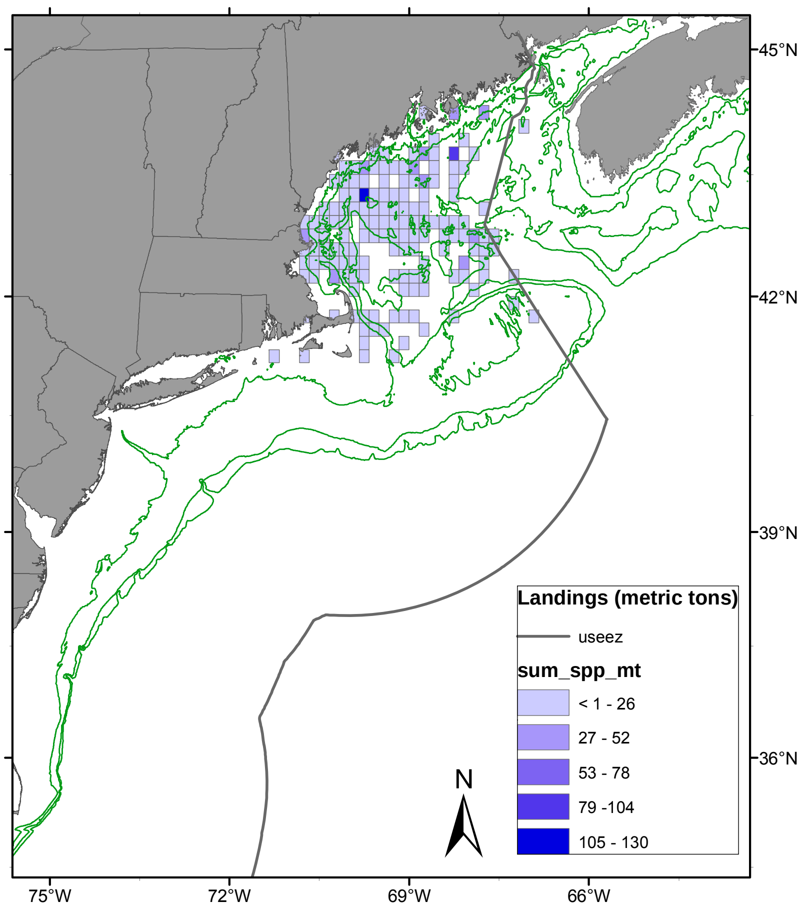


Figure B21. Landings of white hake from the sink gill net fishery from 1975-1979 and 1980-1984.

White Hake Gillnet Landings (1985-1989)



White Hake Gillnet Landings (1990-1994)

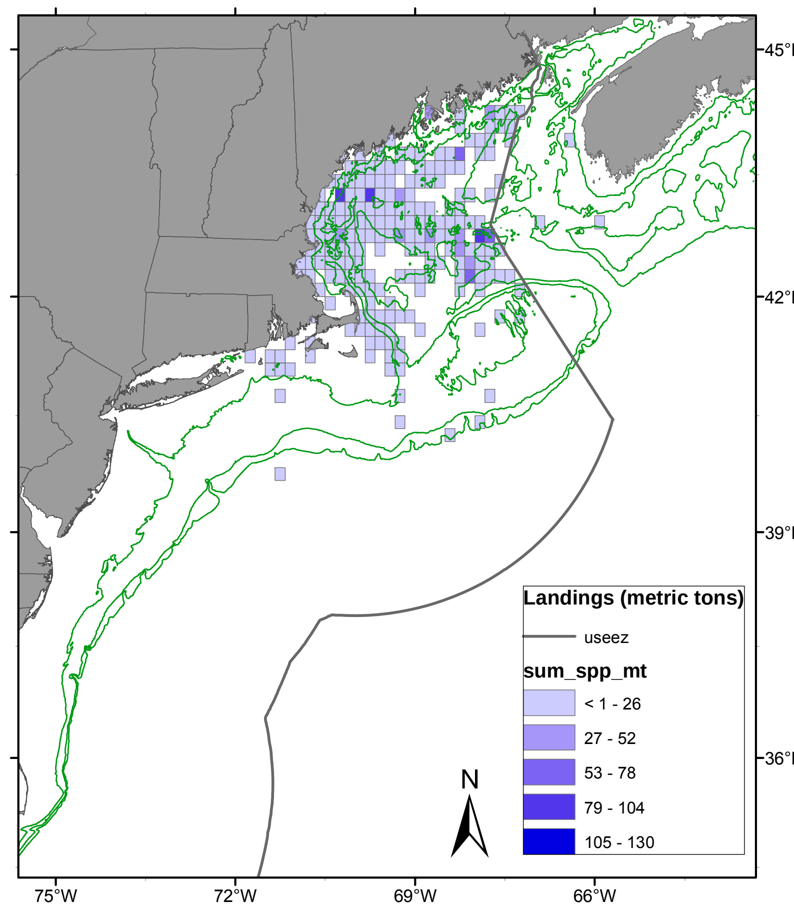
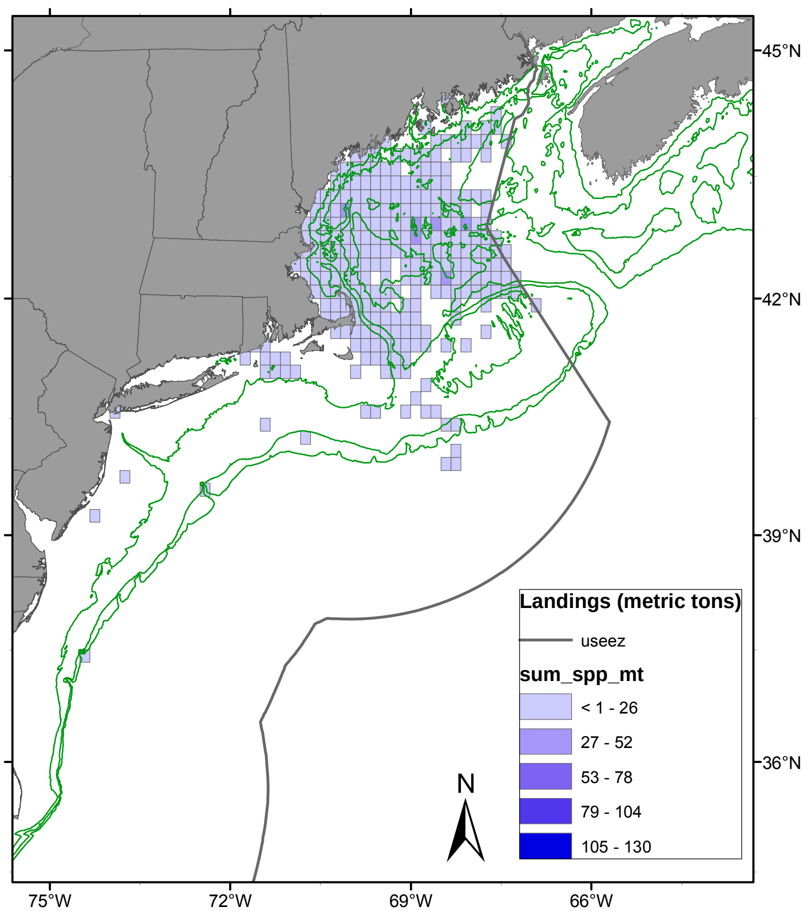


Figure B22. Landings of white hake from the sink gill net fishery from 1985-1989 and 1990-1994.

White Hake Gillnet Landings (1995-1999)



White Hake Gillnet Landings (2000-2004)

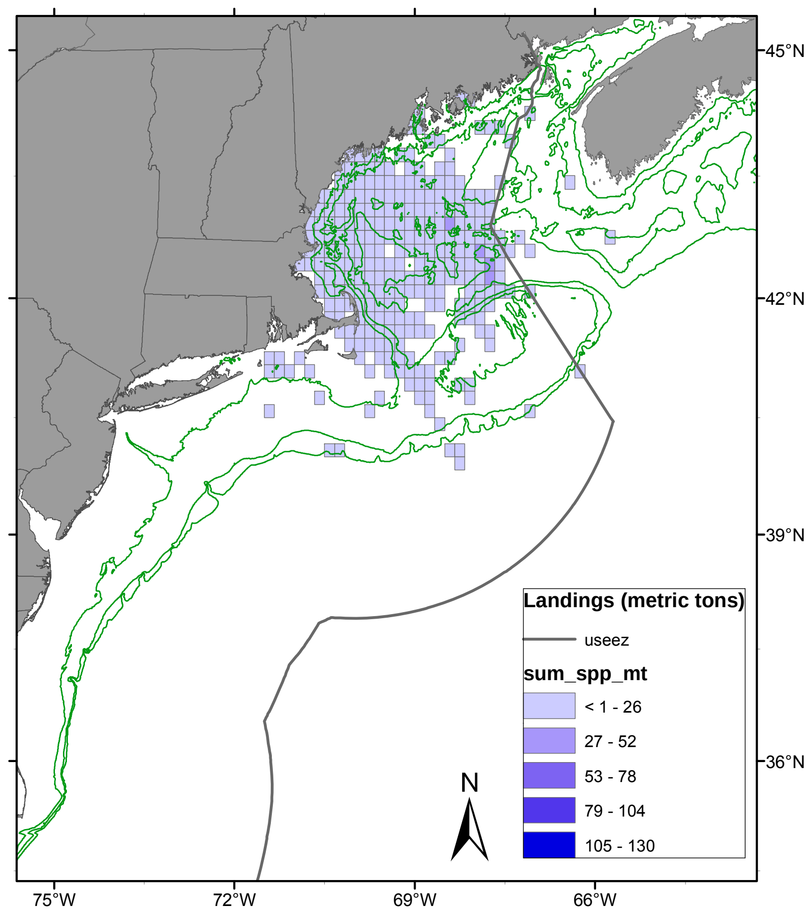


Figure B23. Landings of white hake from the sink gill net fishery from 1995-1999 and 2000-2004.

White Hake Gillnet Landings (2005-2009)

White Hake Gillnet Landings (2010-2011)

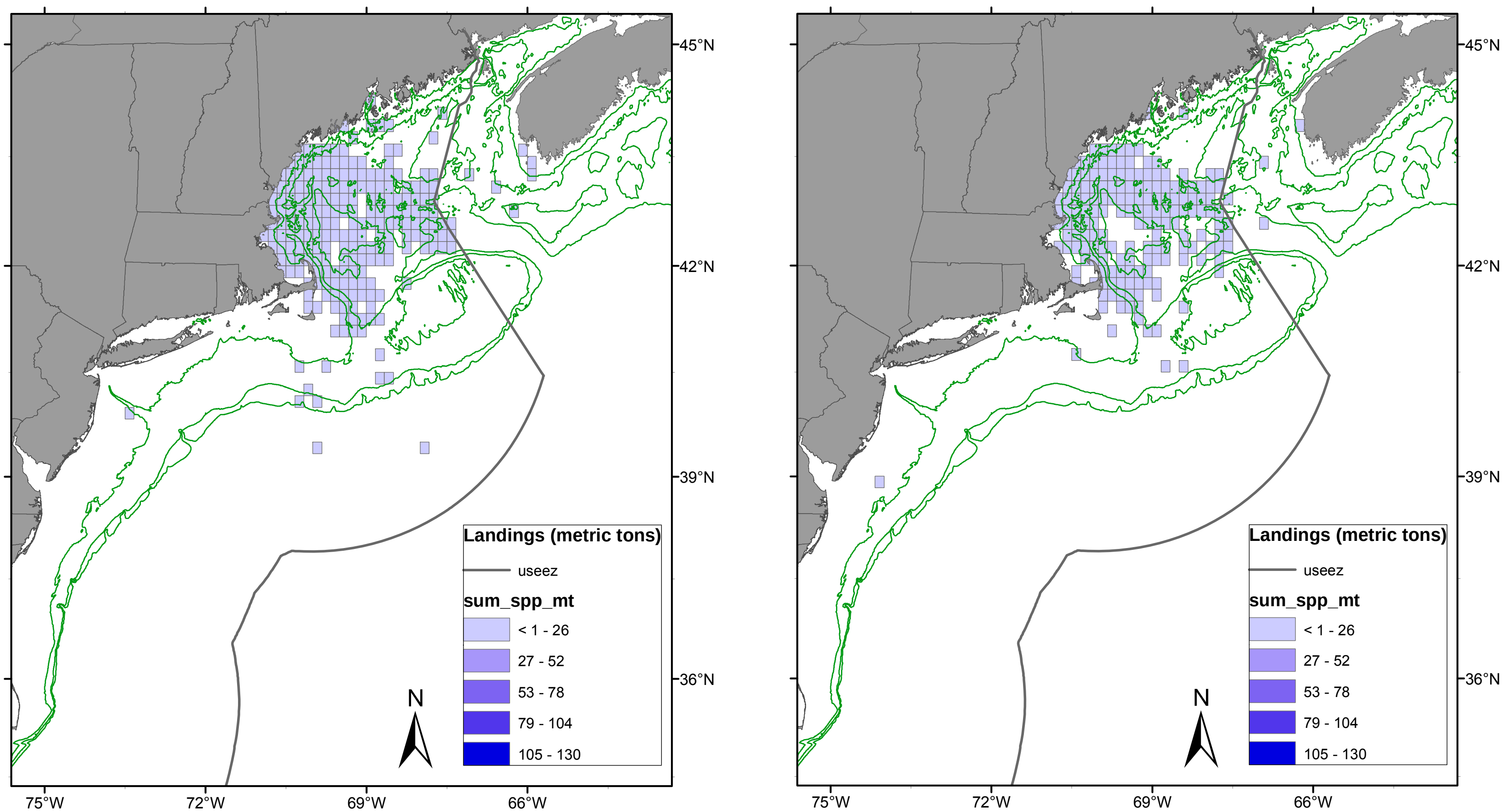
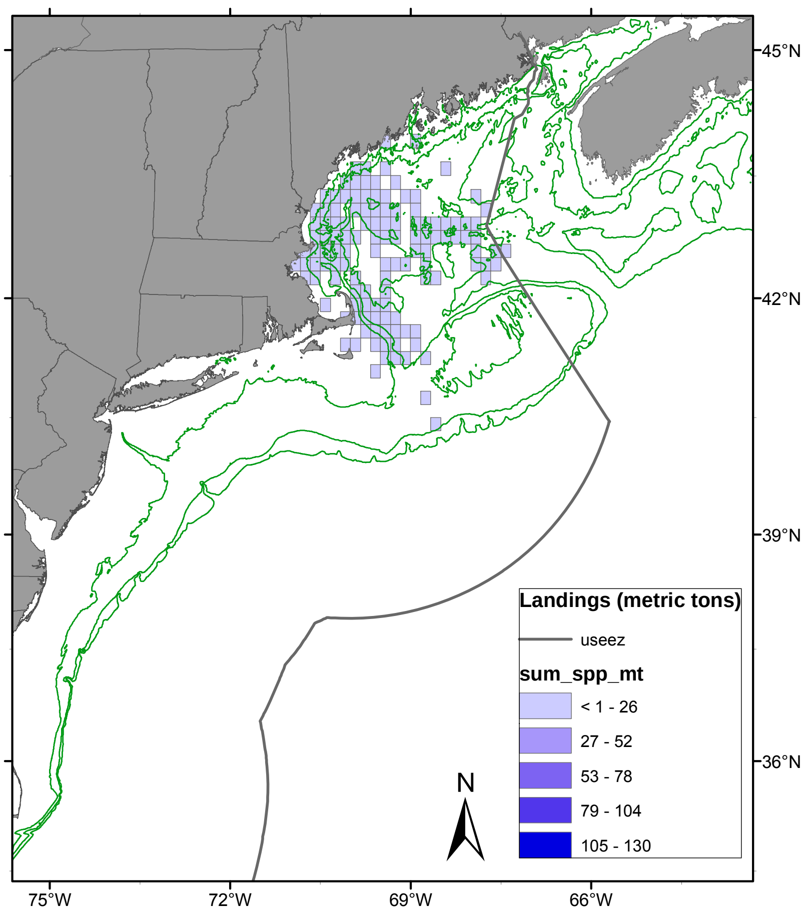


Figure B24. Landings of white hake from the sink gill net fishery from 2005-2009 and 2010-2011.

White Hake Gillnet Landings (2008)



White Hake Gillnet Landings (2009)

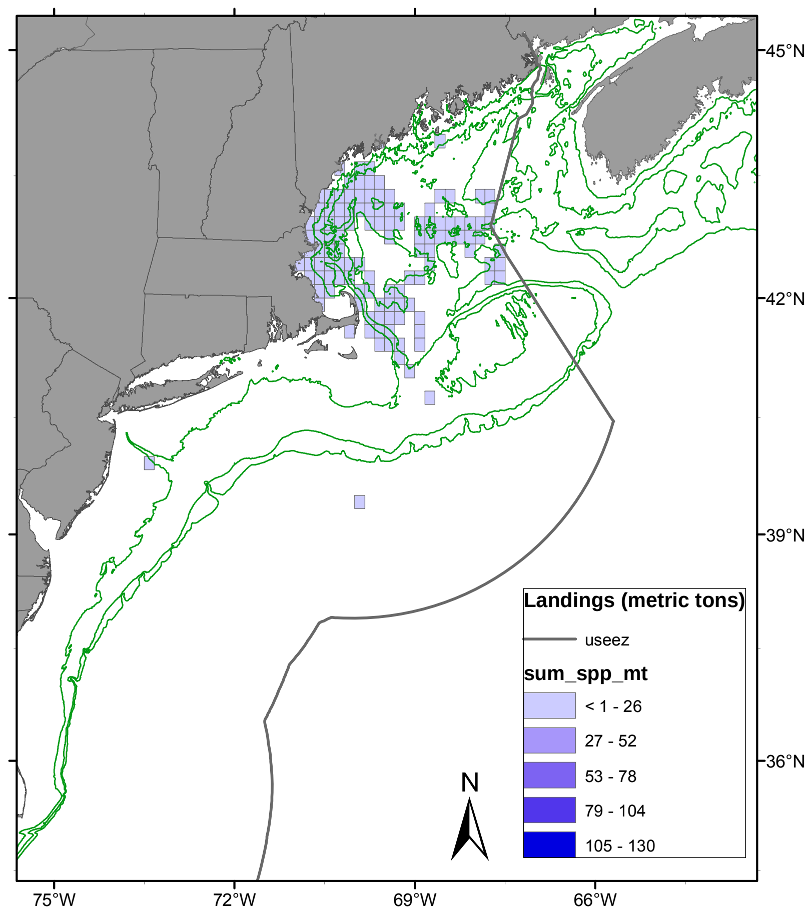


Figure B25a. Landings of white hake from the sink gill net fishery from 2008-2011.

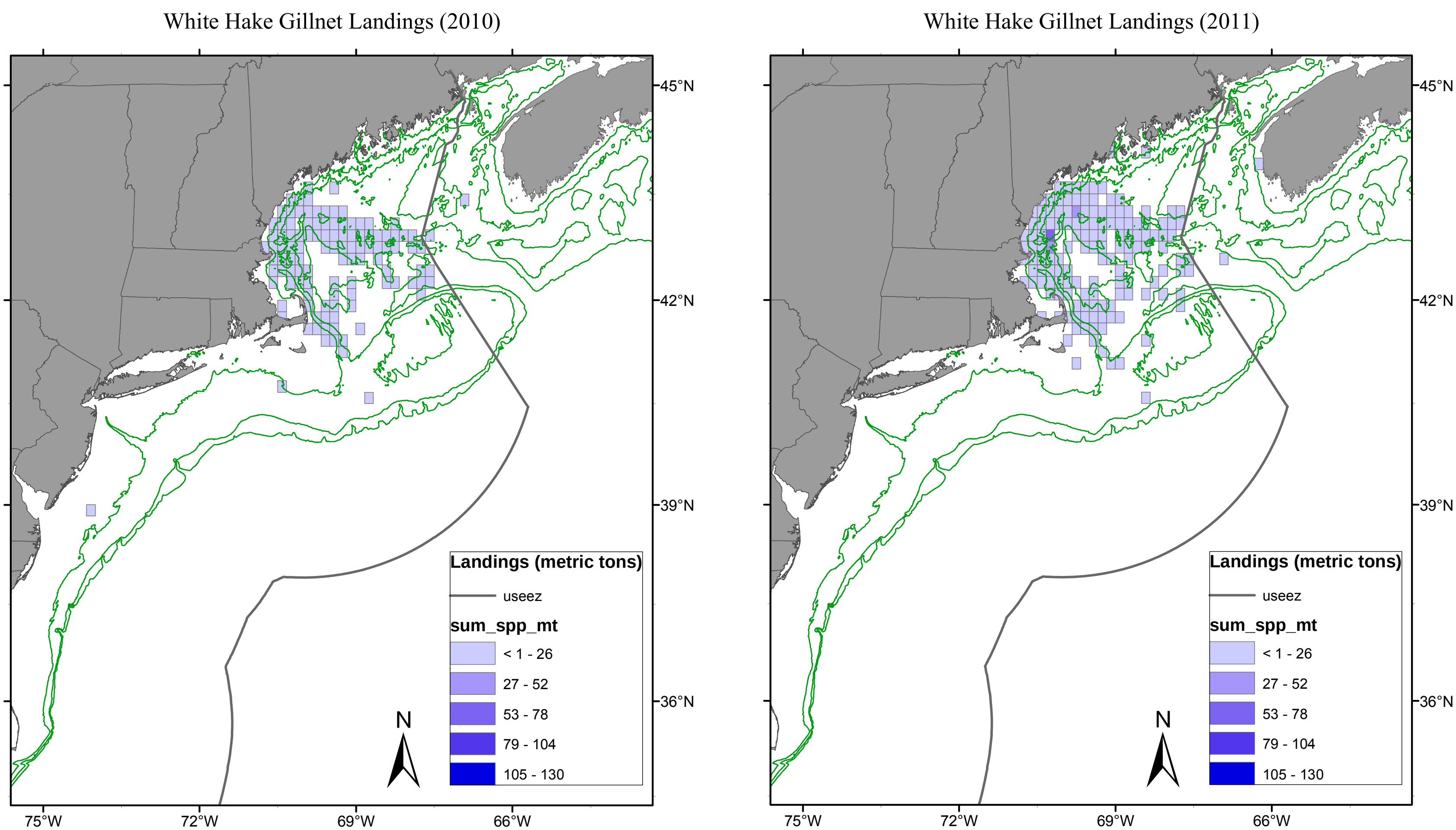
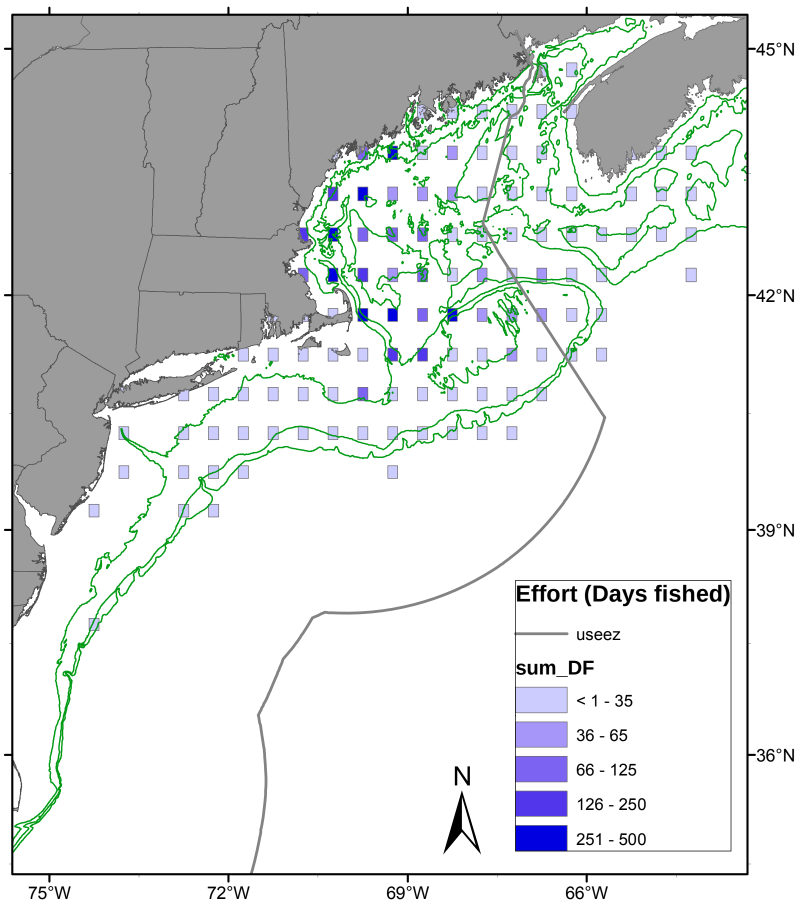


Figure B25b. Landings of white hake from the sink gill net fishery from 2008-2011.

White Hake Otter Trawl Effort (1975-1979)



White Hake Otter Trawl Effort (1980-1984)

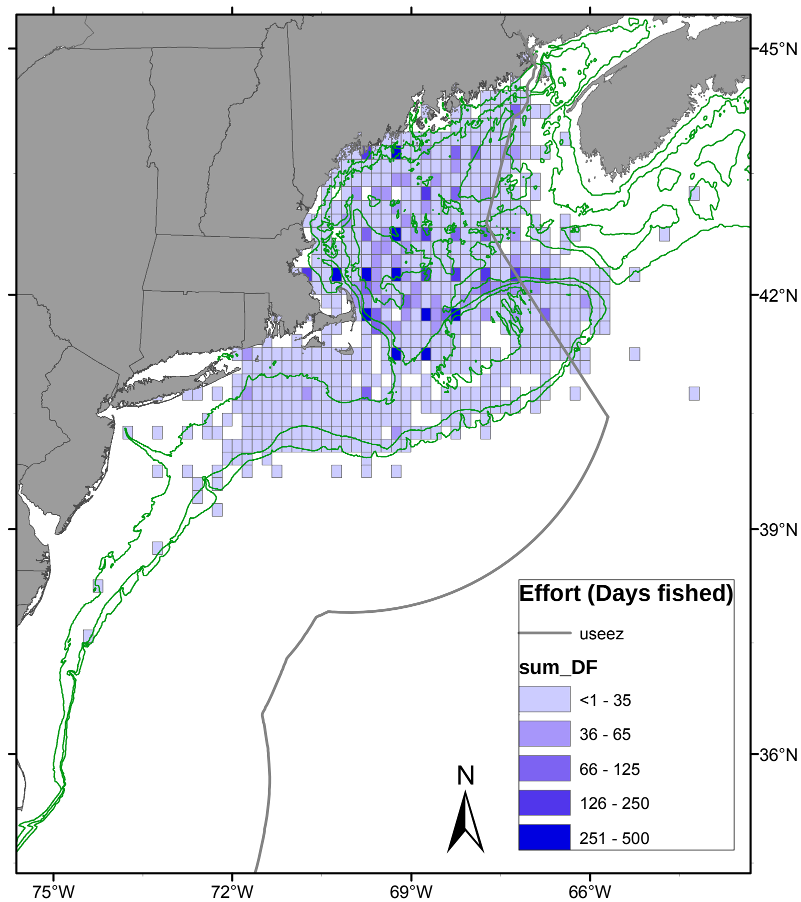
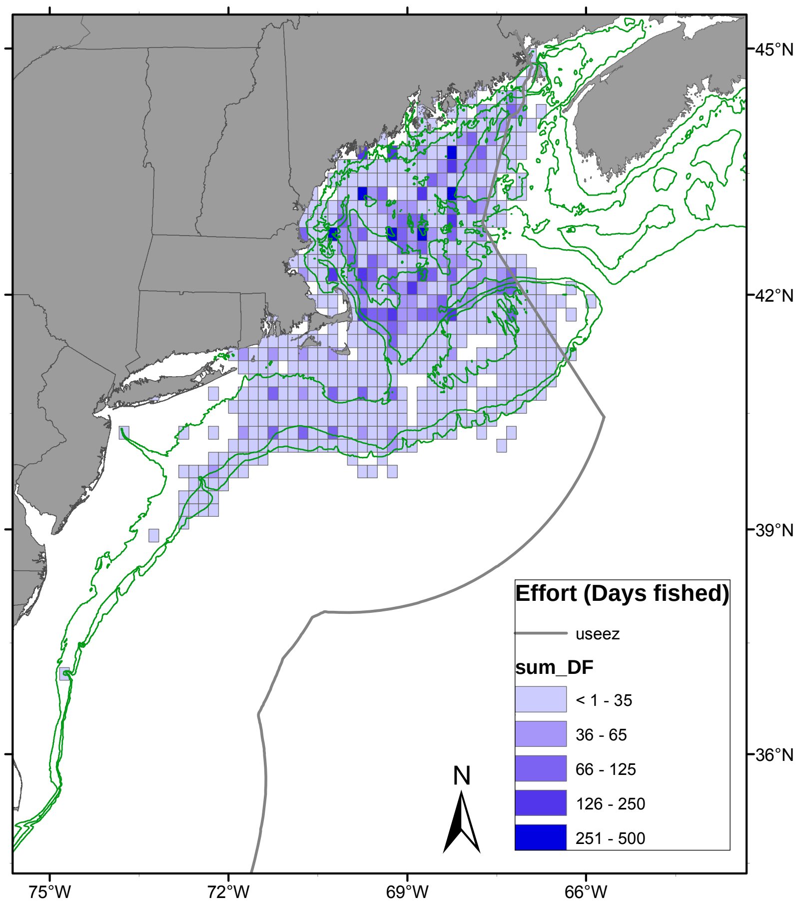


Figure B26. Days fished for trips that landed white hake from the otter trawl fishery from 1975-1979 and 1980-1984.

White Hake Otter Trawl Effort (1985-1989)



White Hake Otter Trawl Effort (1990-1994)

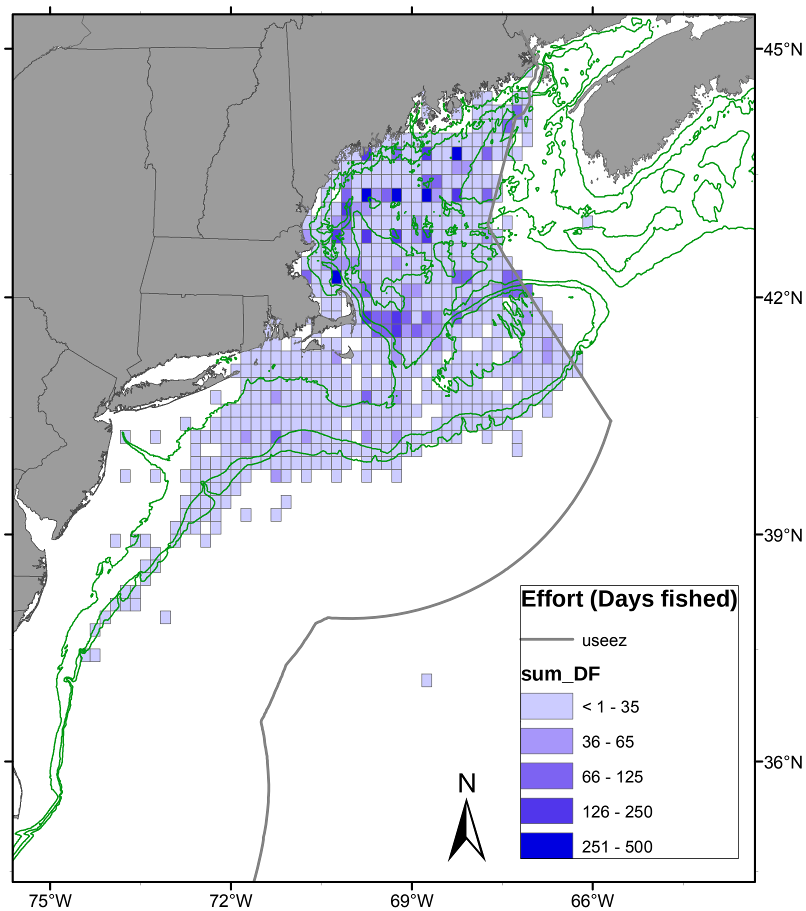


Figure B27. Days fished for trips that landed white hake from the otter trawl fishery from 1985-1989 and 1990-1994.

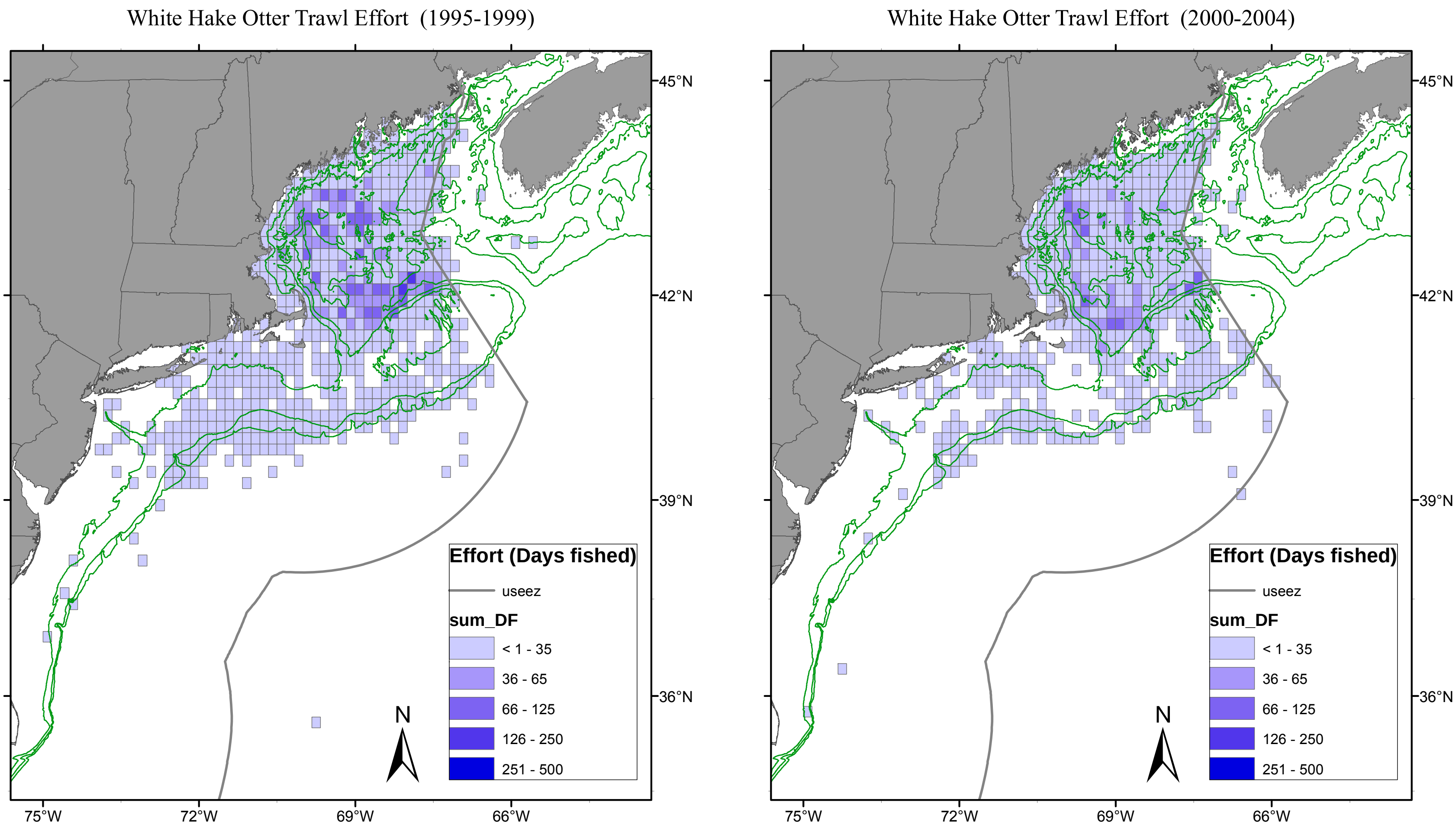
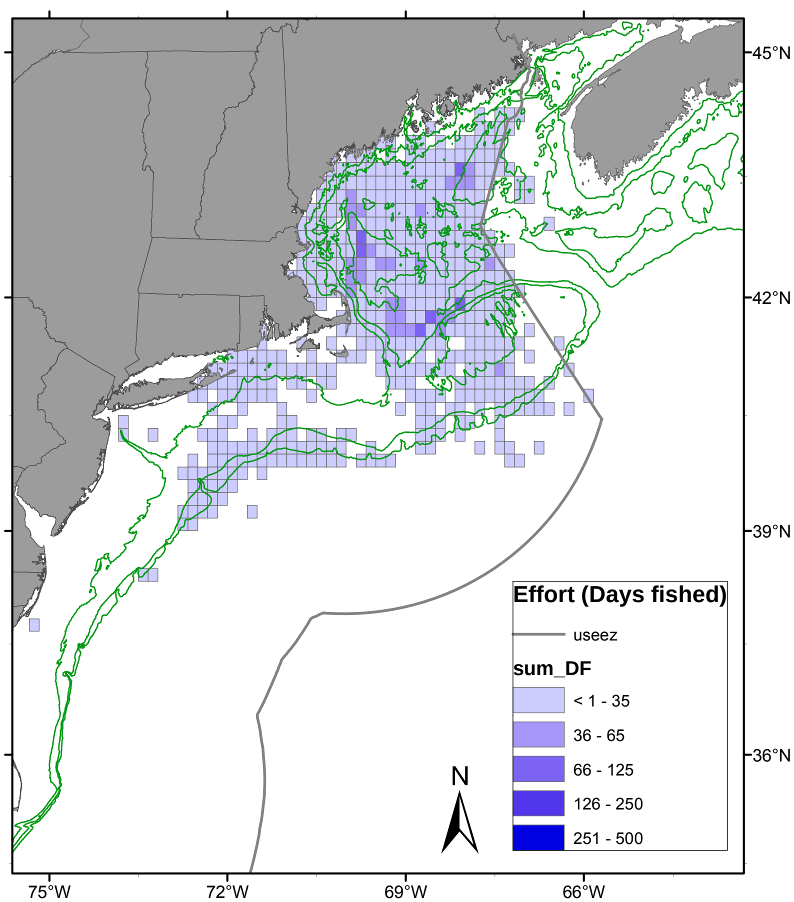


Figure B28. Days fished for trips that landed white hake from the otter trawl fishery from 1995-1999 and 2000-2004.

White Hake Otter Trawl Effort (2005-2009)



White Hake Otter Trawl Effort (2010-2011)

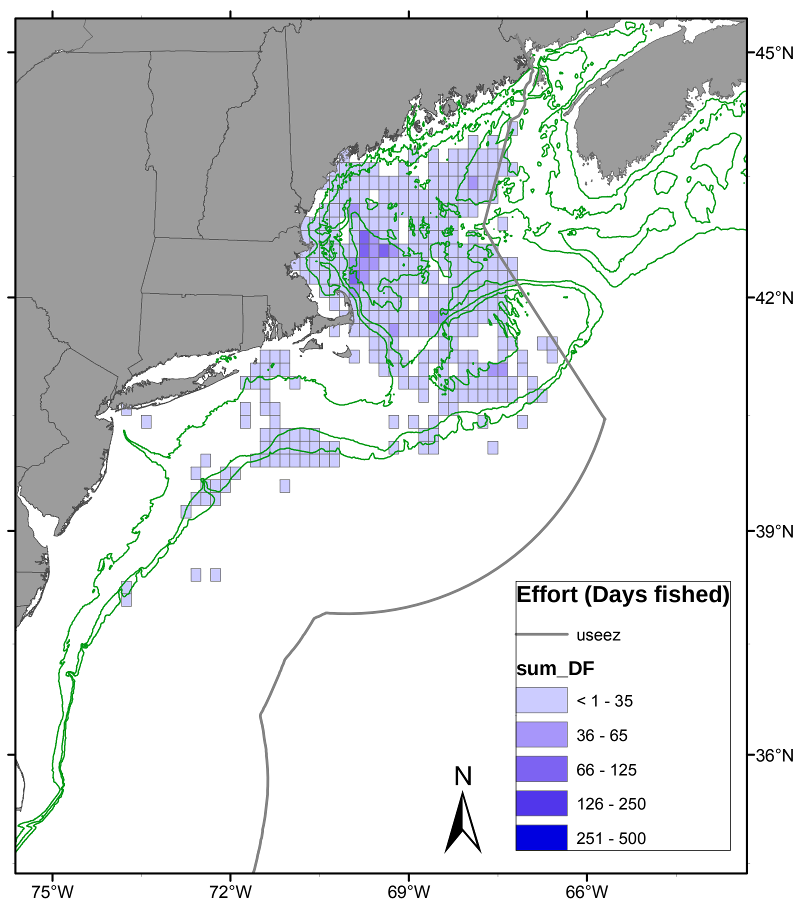


Figure B29. Days fished for trips that landed white hake from the otter trawl fishery from 2005-2009 and 2010-2011.

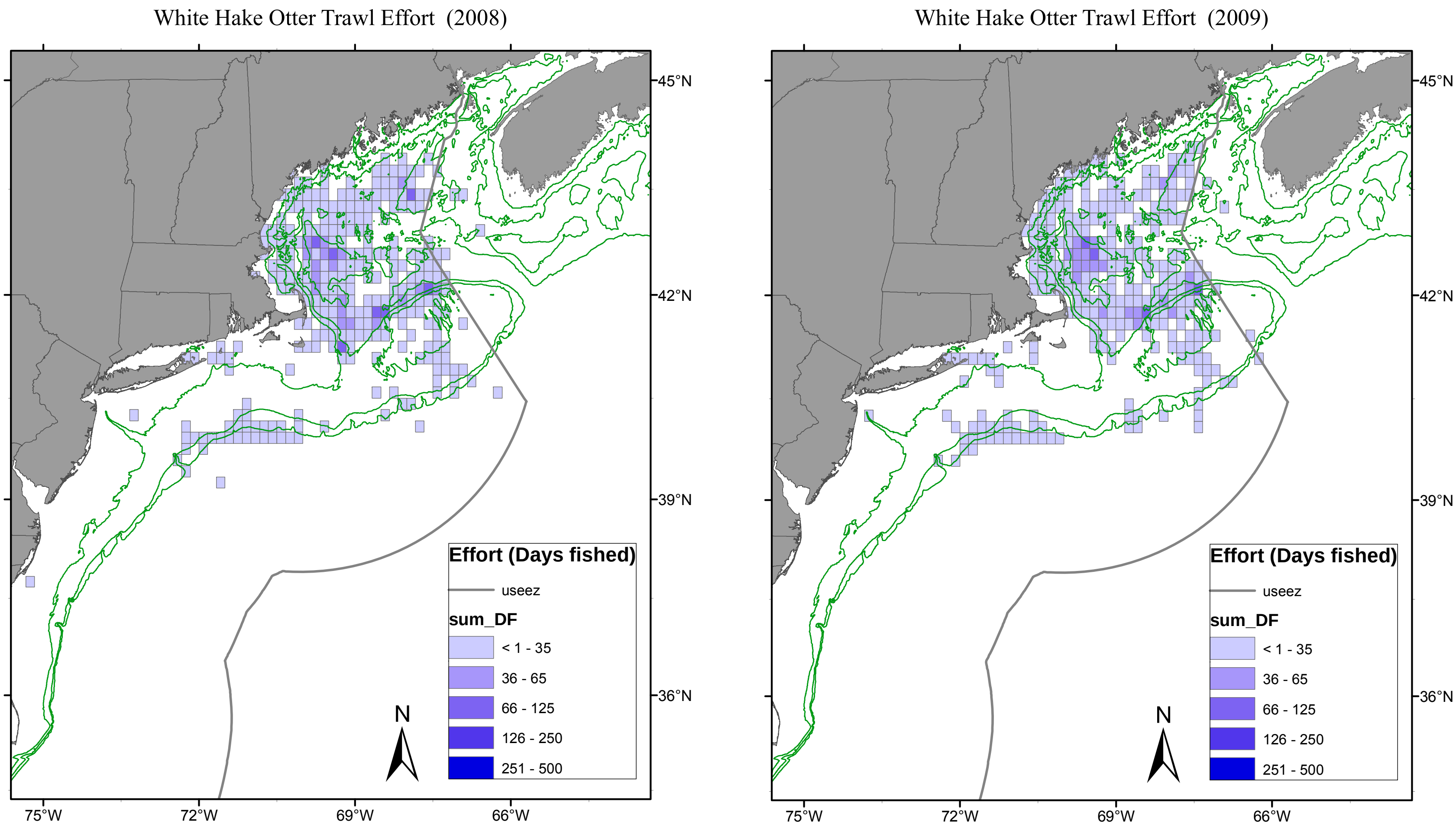


Figure B30a. Days fished for trips that landed white hake from the otter trawl fishery from 2008-2011.

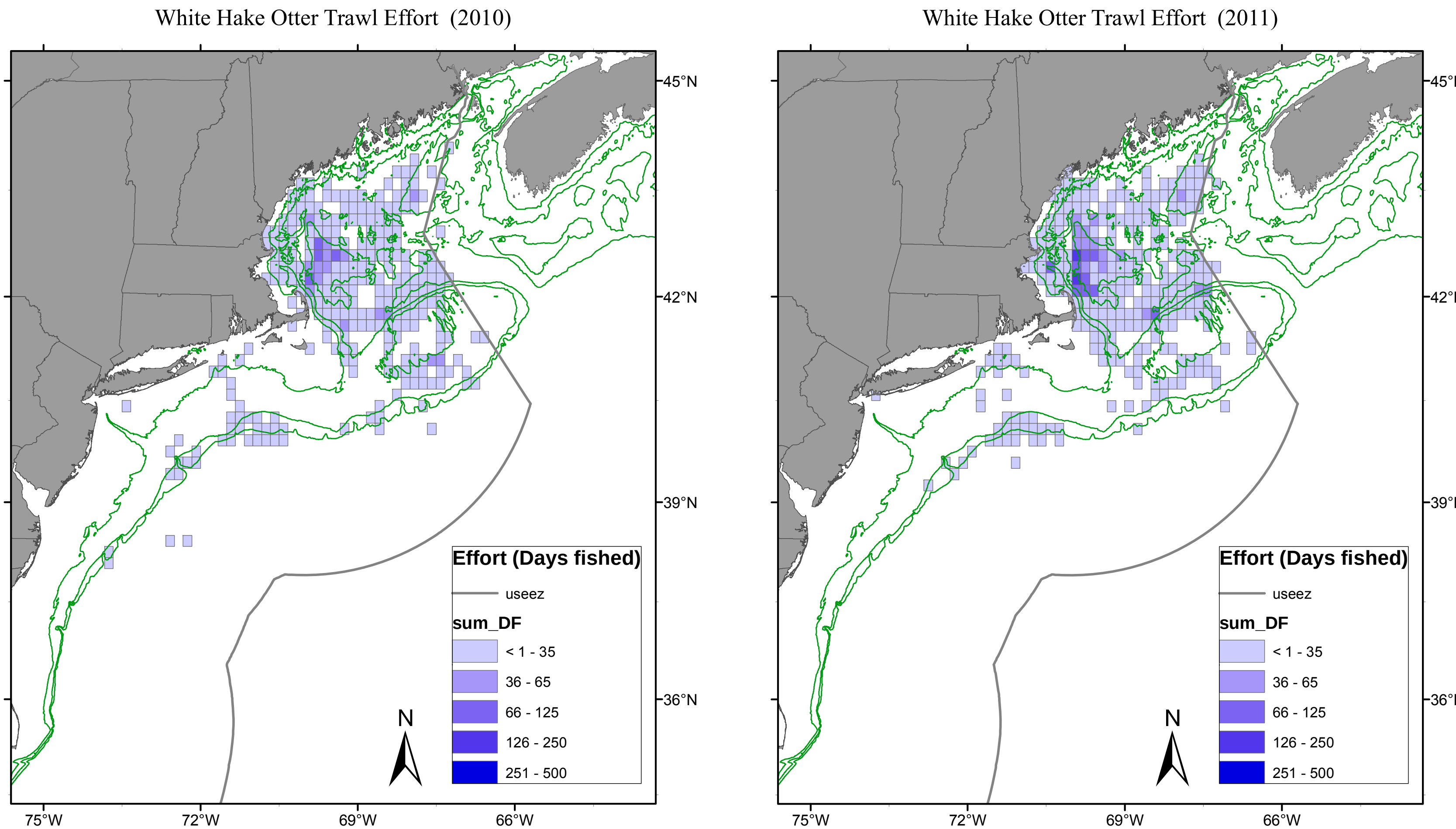


Figure B30b. Days fished for trips that landed white hake from the otter trawl fishery from 2008-2011.

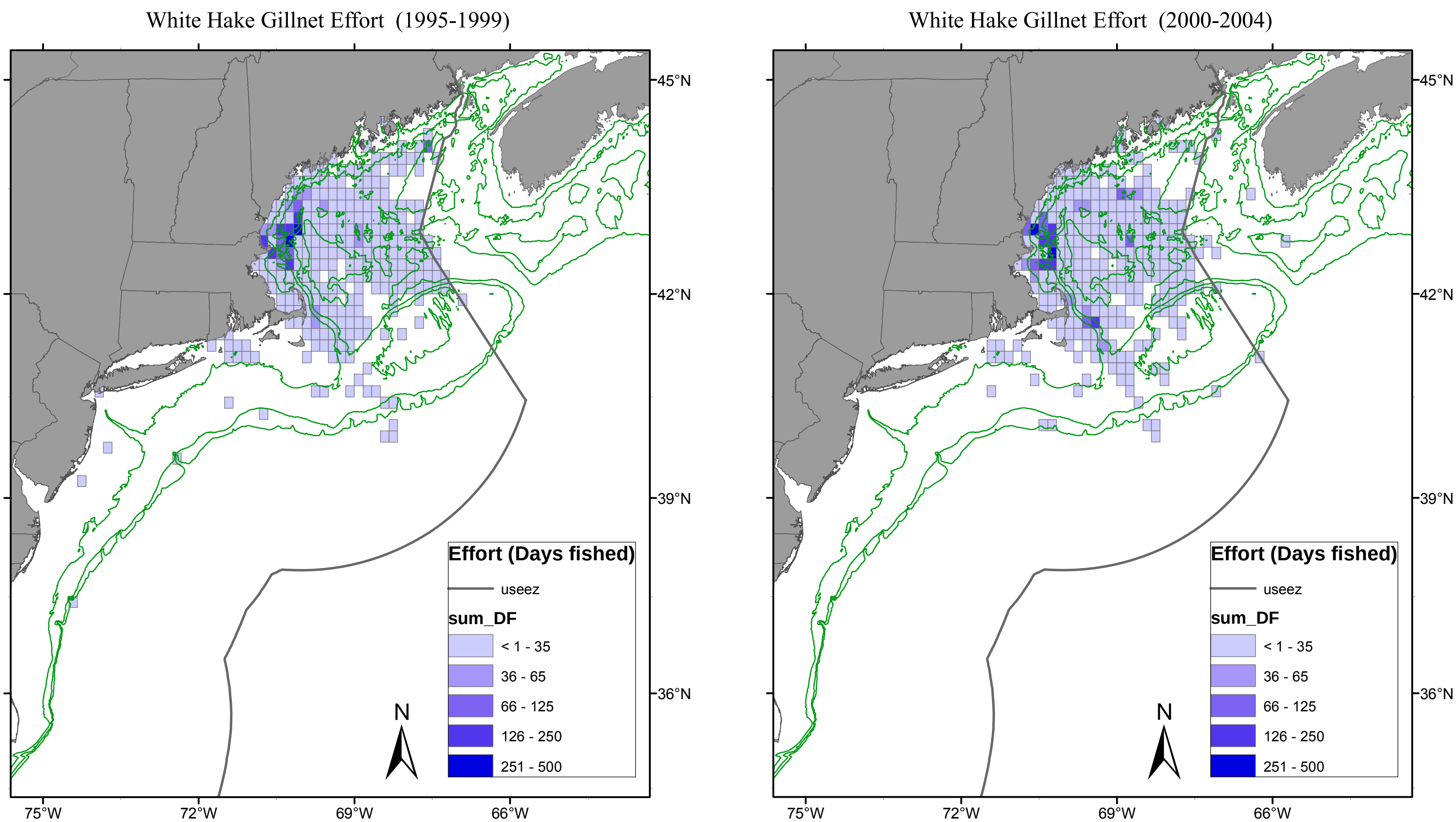


Figure B31. Days fished for trips that landed white hake from the sink gill net fishery from 1995-1999 and 2000-2004.

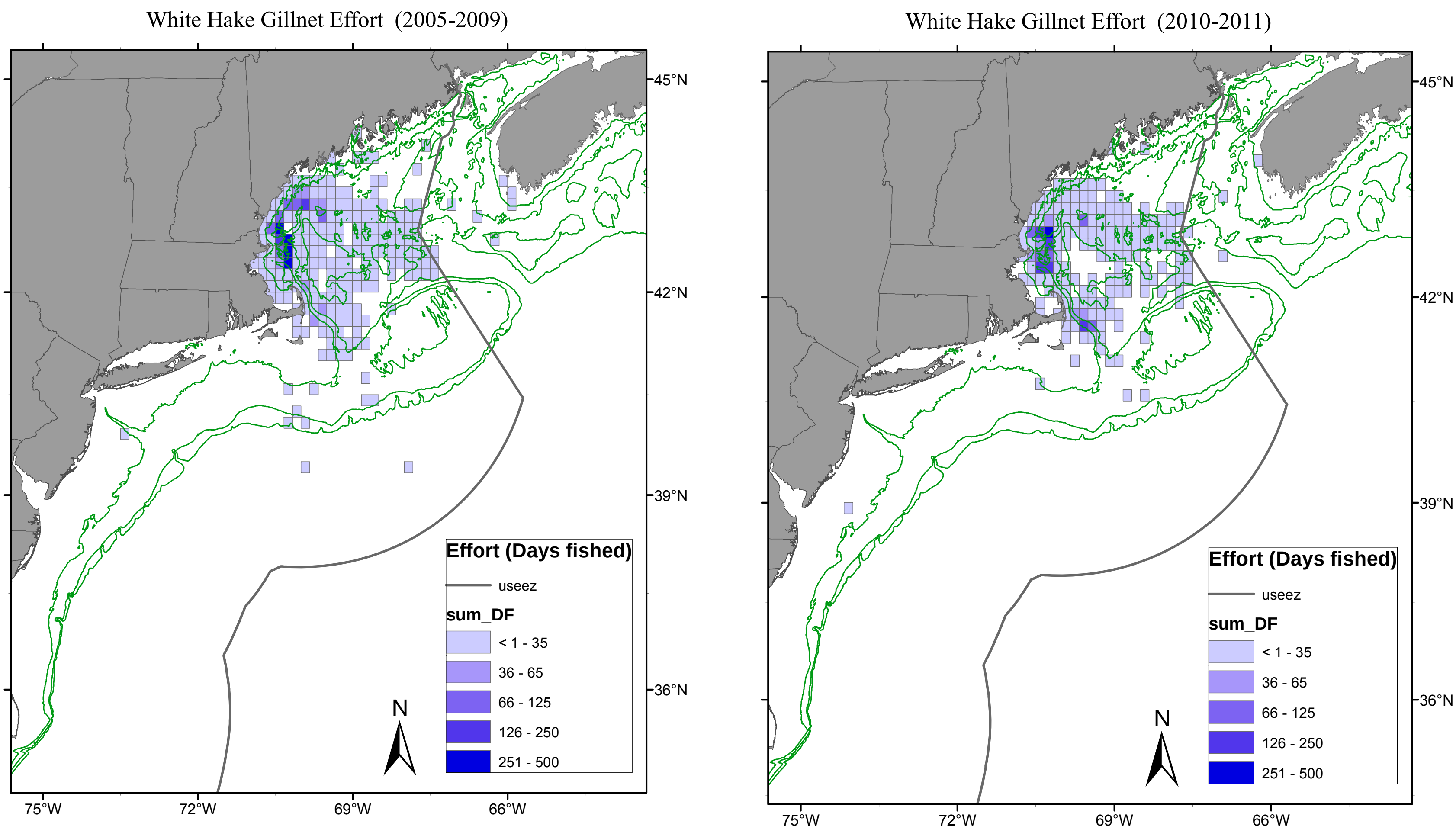


Figure B32. Days fished for trips that landed white hake from the sink gill net fishery from 2005-2009 and 2010-2011.

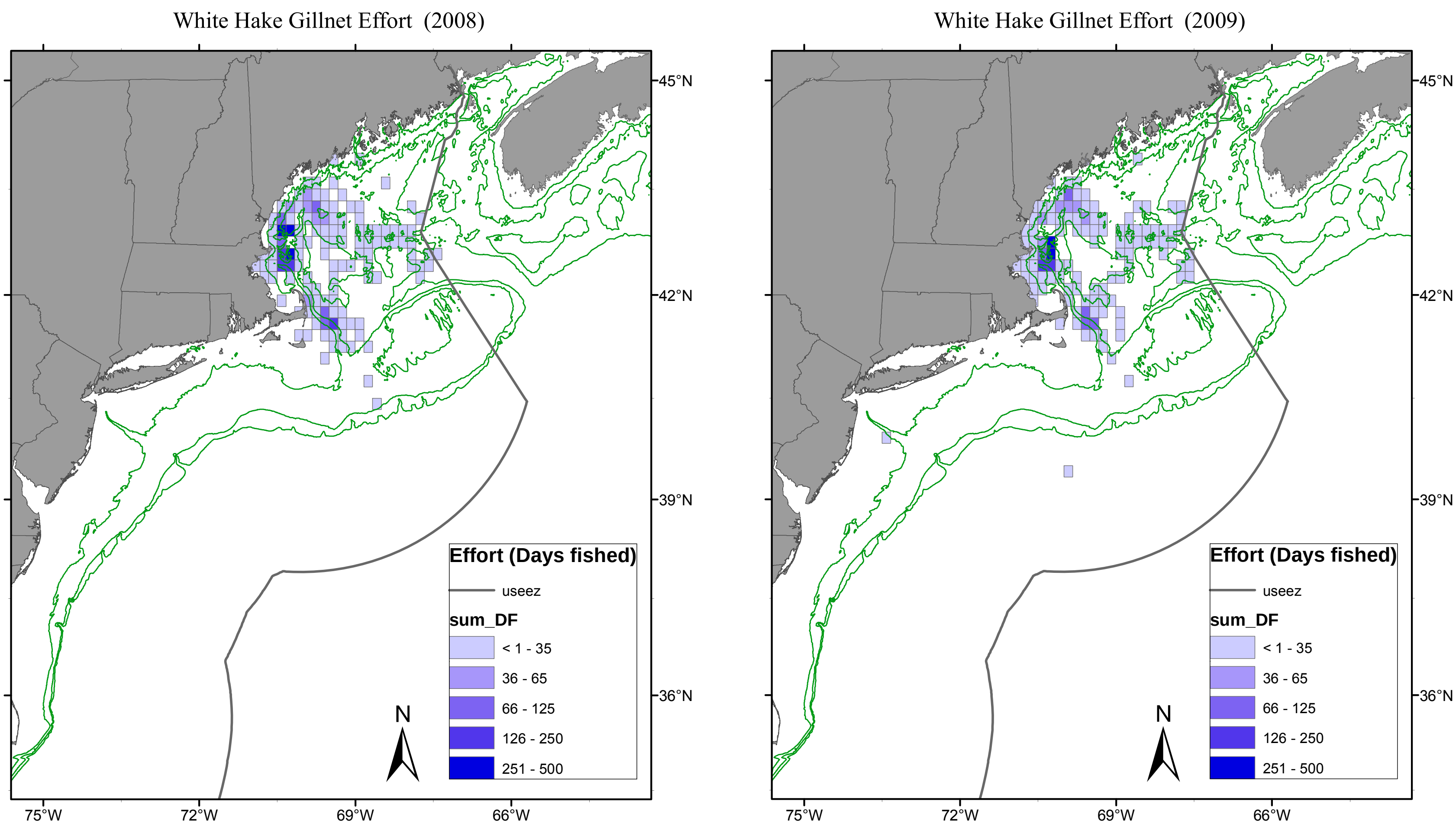
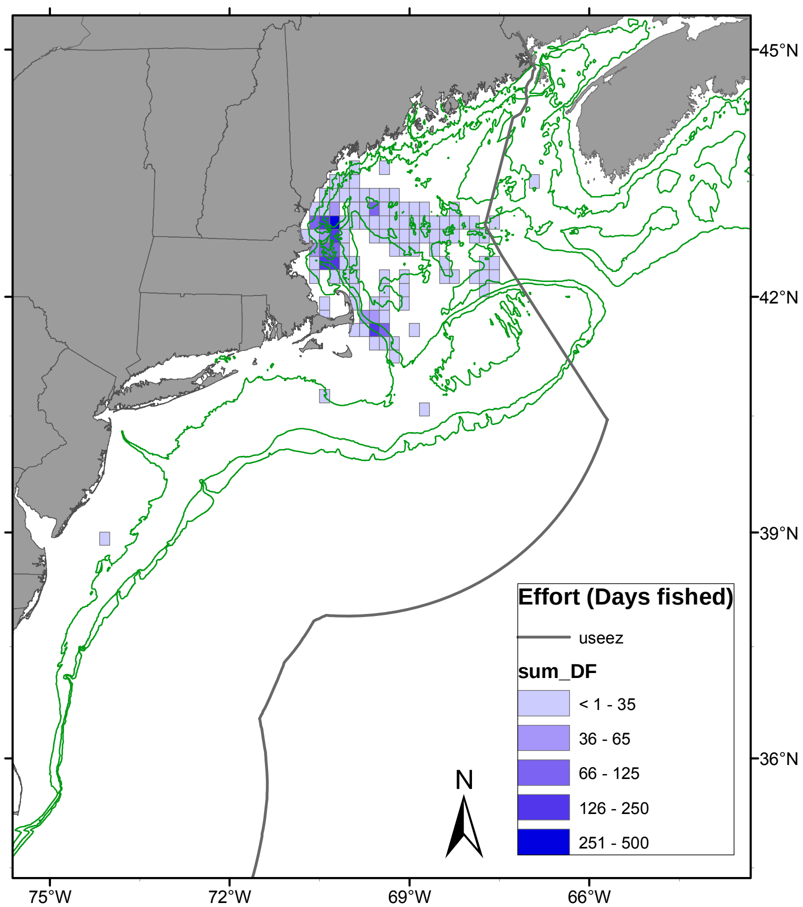


Figure B33a. Days fished for trips that landed white hake from the sink gill net fishery from 2008-2011.

White Hake Gillnet Effort (2010)



White Hake Gillnet Effort (2011)

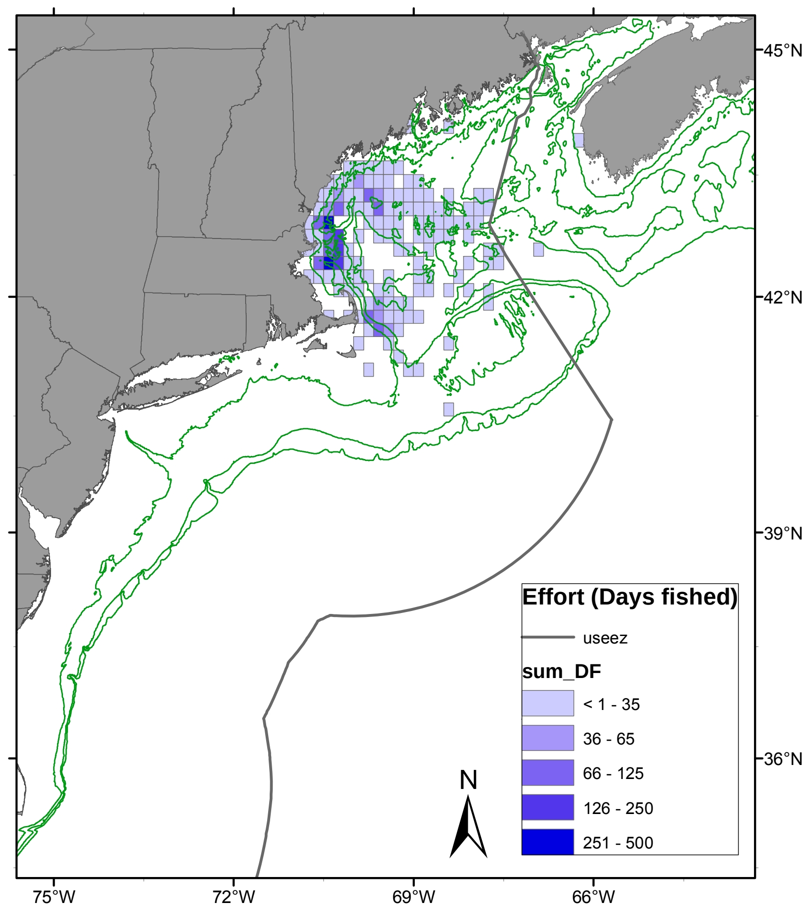


Figure B33b. Days fished for trips that landed white hake from the sink gill net fishery from 2008-2011.

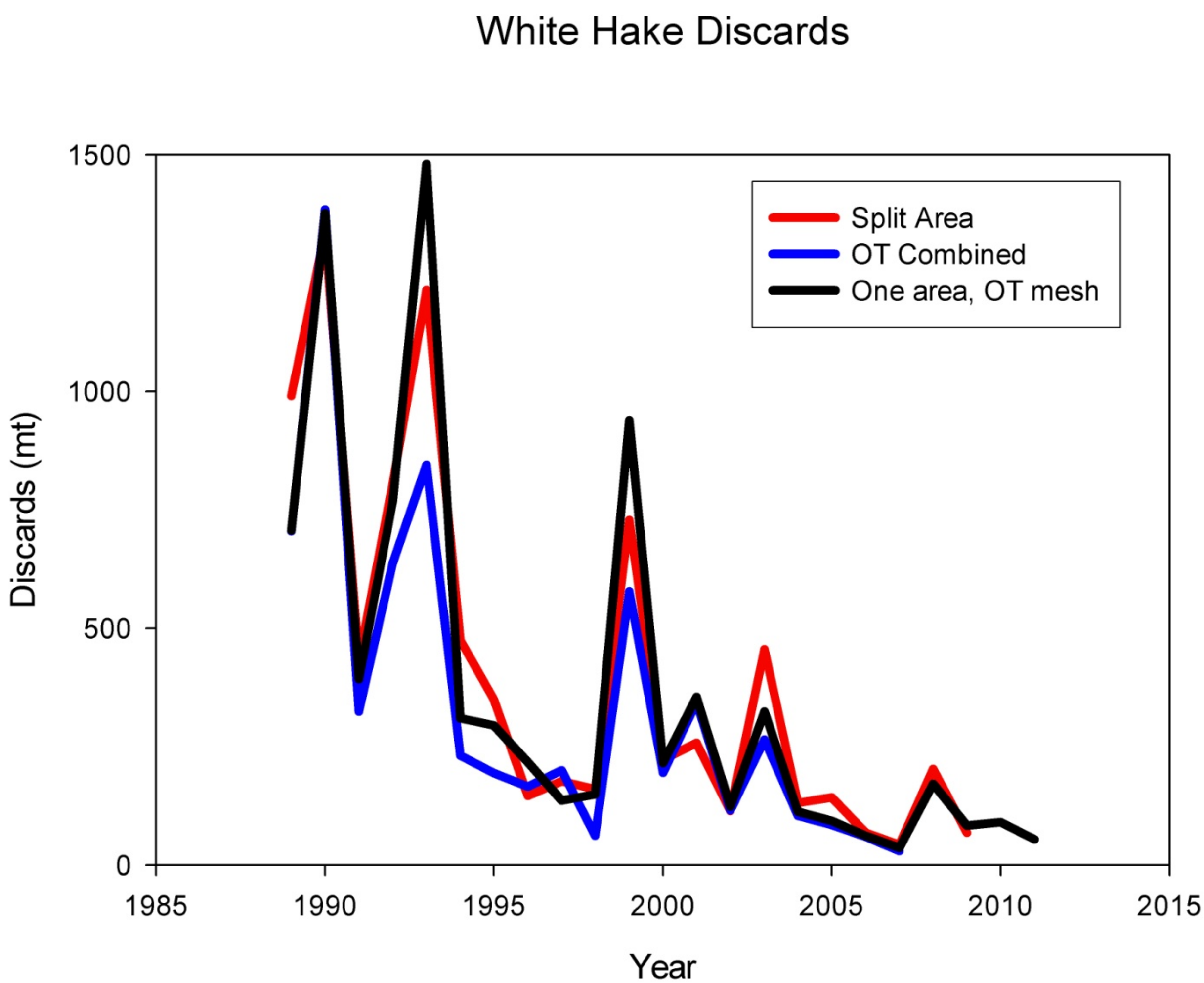


Figure B34. Discards of white hake using three different stratification schemes. The red line uses two areas as in the red hake assessment (NEFSC 2011), the blue line combines otter trawl small and large mesh (Butterworth et al 2008), and the black line uses one fishing area and splits mesh size (this assessment).

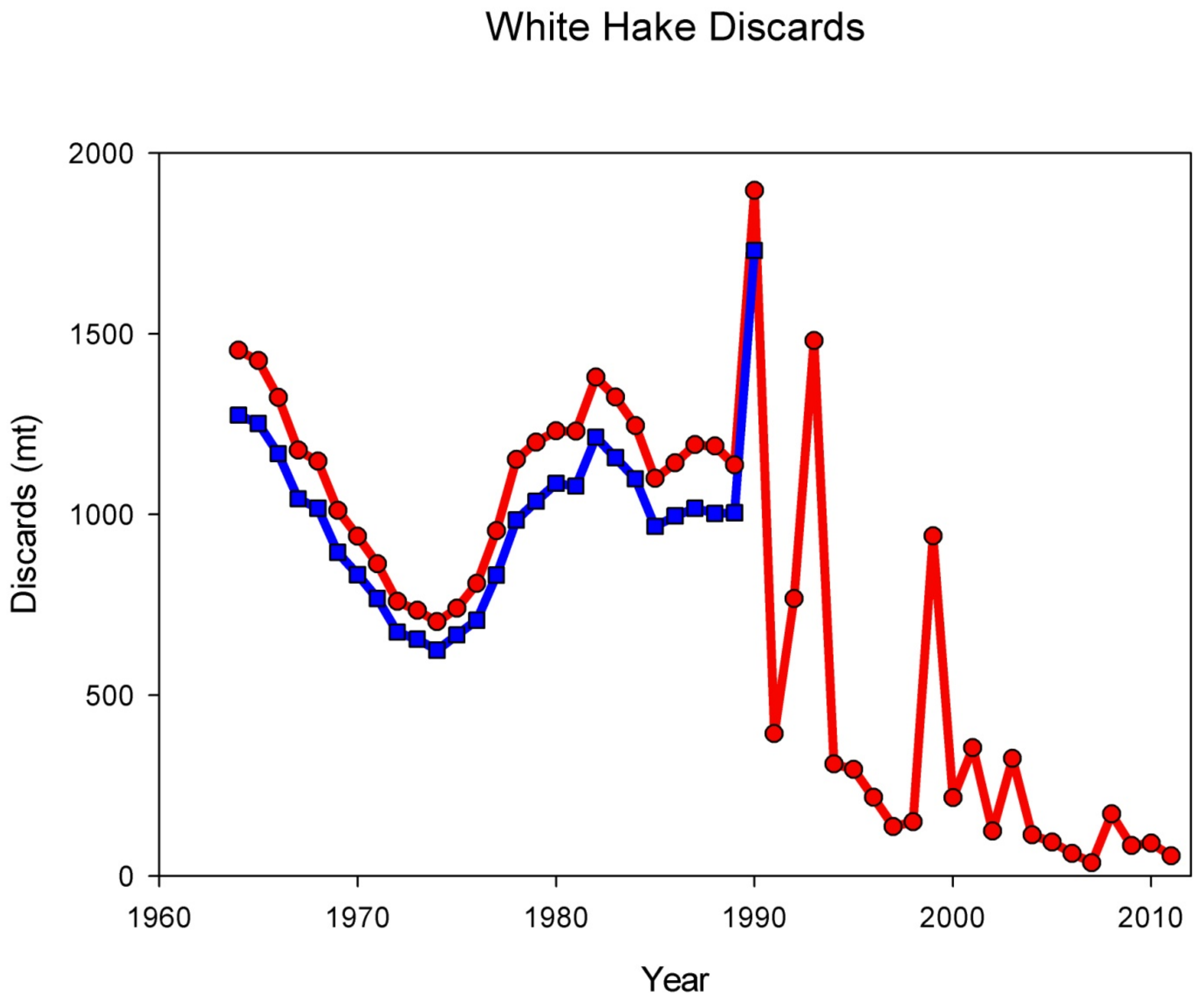


Figure B35. Discards of white hake using two time periods for hind-casting. A three-year average was used for the red circles and a five-year average for the blue squares.

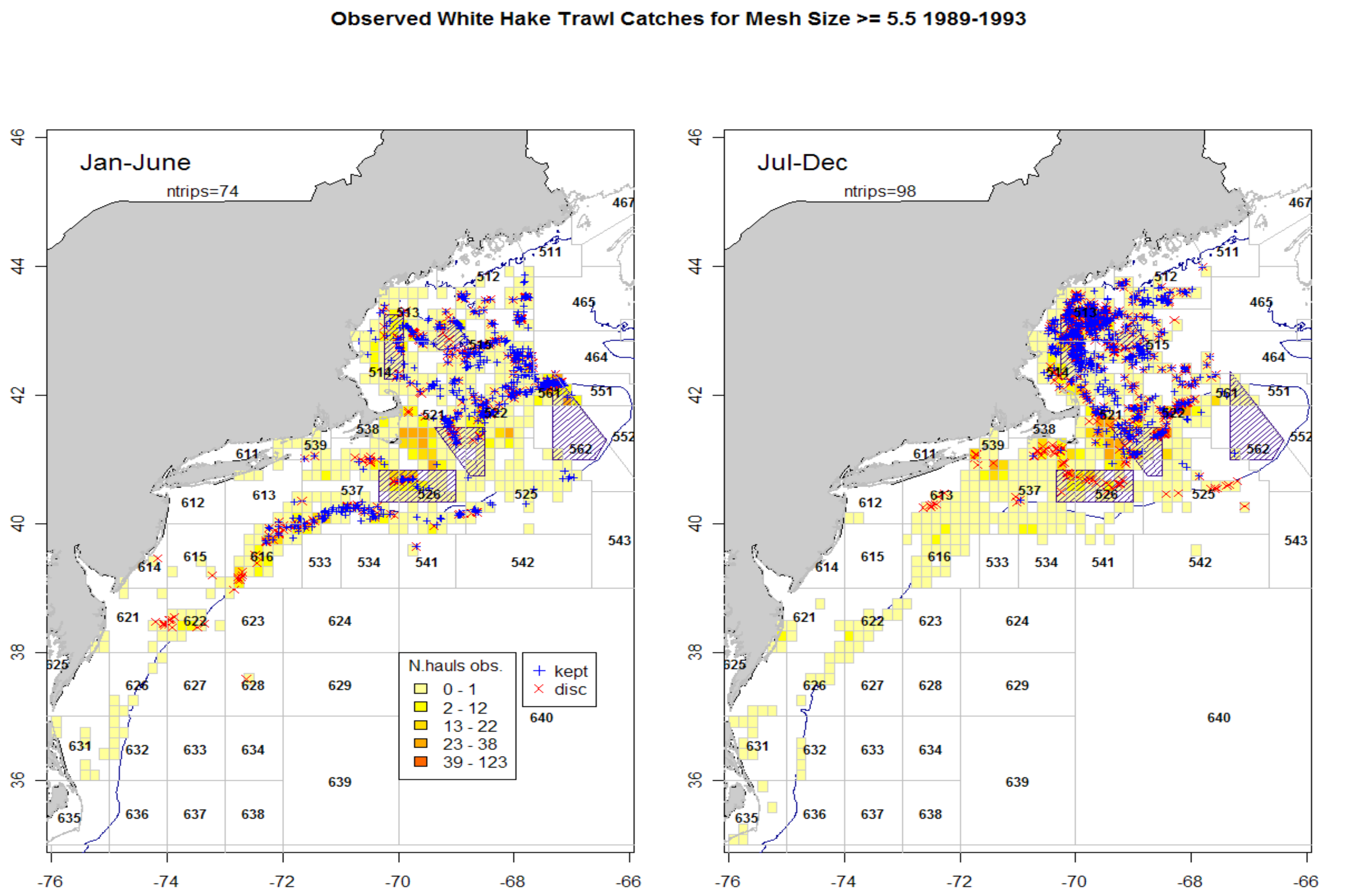


Figure B36. Observed kept and discarded white hake from 1989-1993 in the large-mesh otter trawl fishery.

Observed White Hake Trawl Catches for Mesh Size >= 5.5 1995-1999

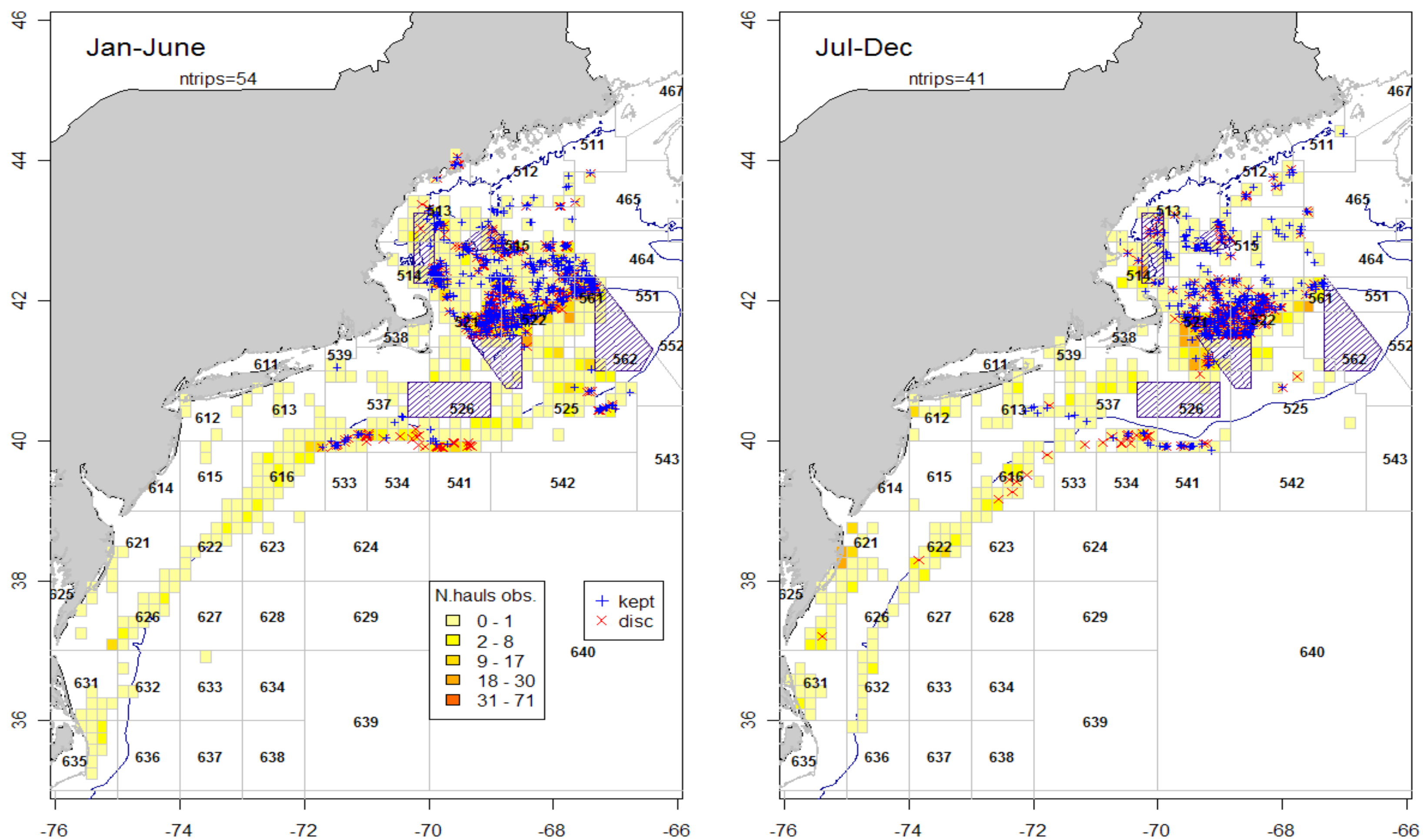


Figure B37. Observed kept and discarded white hake from 1995-1999 in the large-mesh otter trawl fishery.

Observed White Hake Trawl Catches for Mesh Size >= 5.5 2001-2005

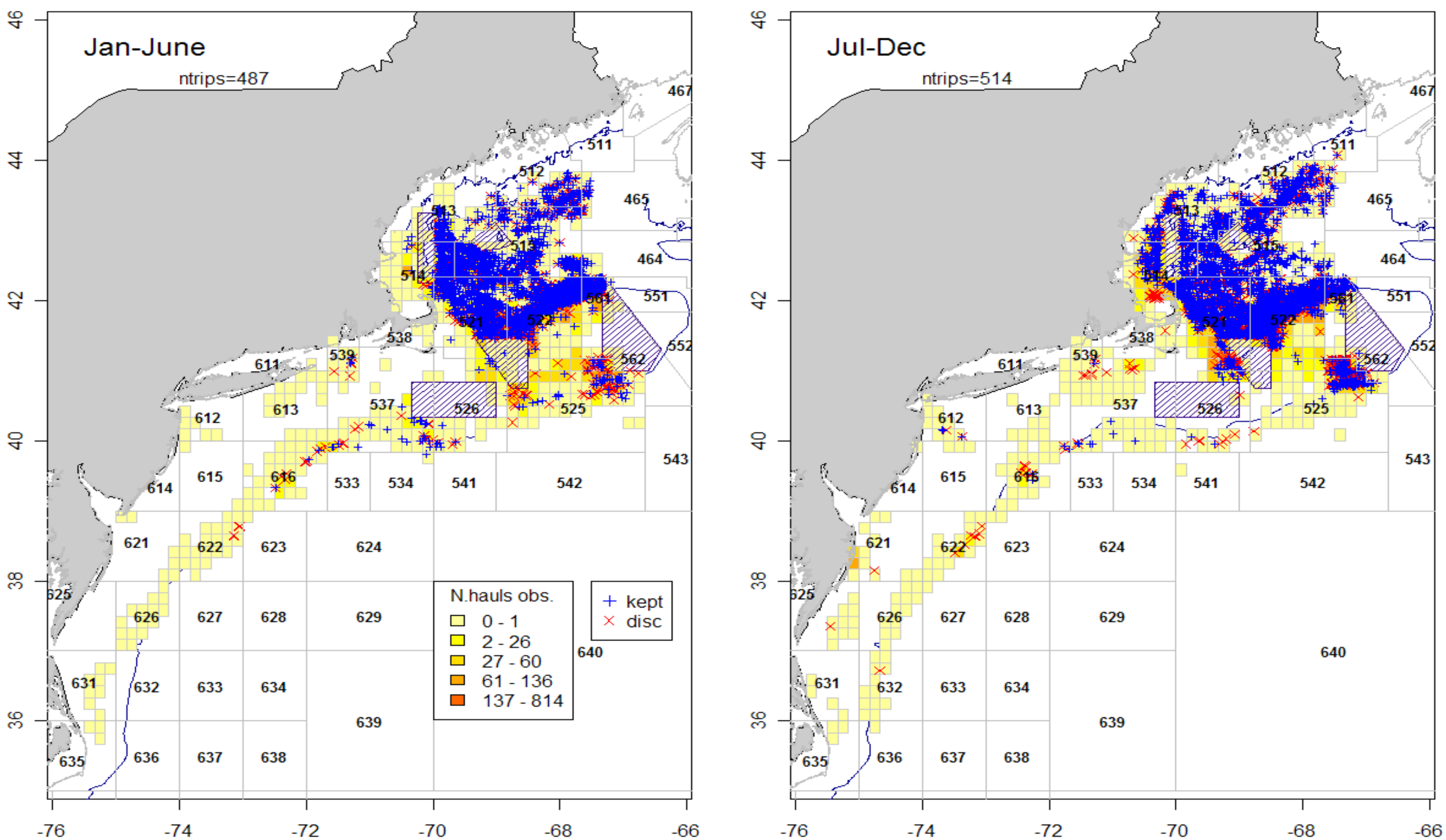


Figure B38. Observed kept and discarded white hake from 2001-2005 in the large-mesh otter trawl fishery.

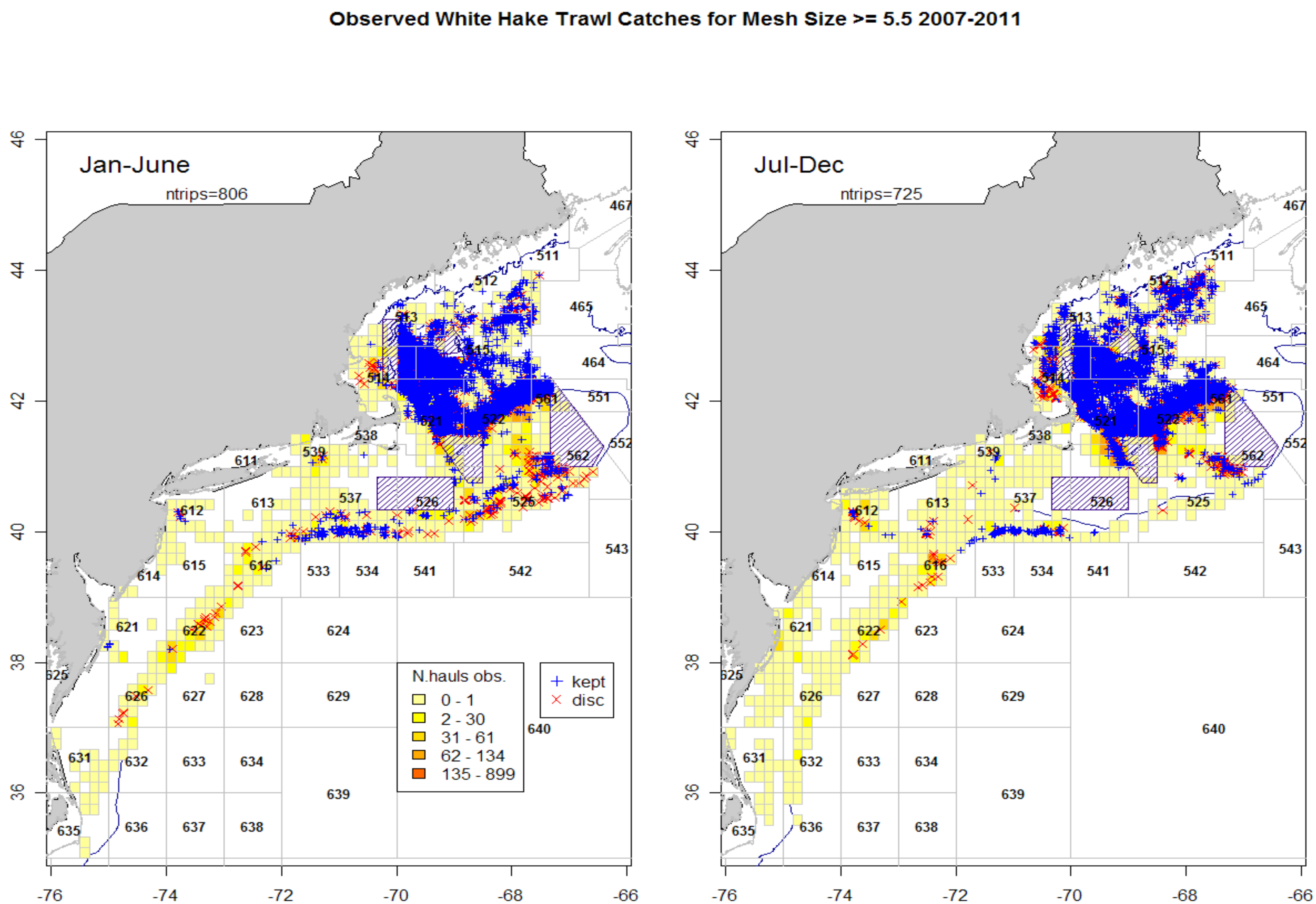


Figure B39. Observed kept and discarded white hake from 2007-2011 in the large-mesh otter trawl fishery.

Observed White Hake Trawl Catches for Mesh Size < 5.5 1989-1993

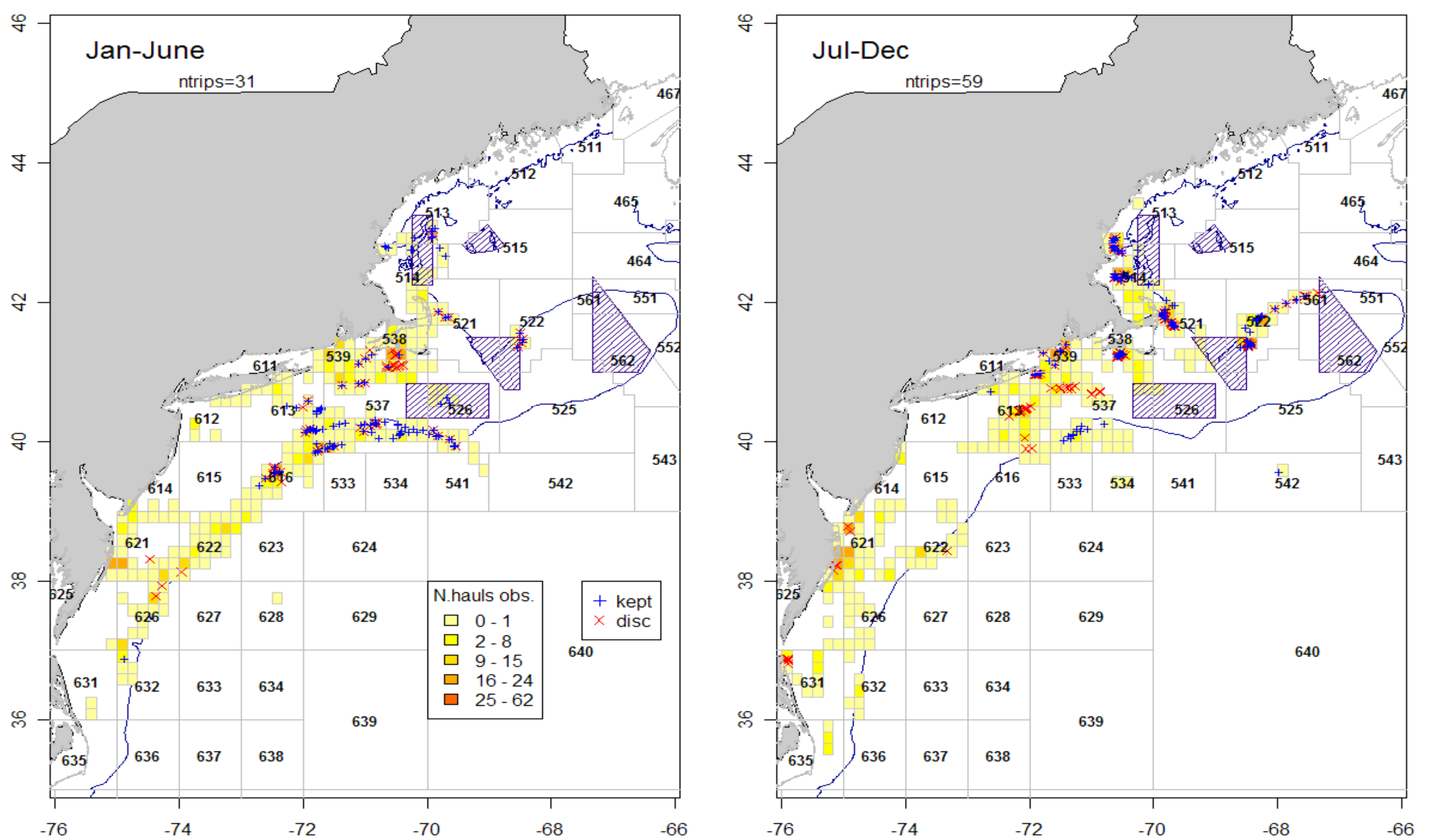


Figure B40. Observed kept and discarded white hake from 1989-1993 in the small-mesh otter trawl fishery.

Observed White Hake Trawl Catches for Mesh Size < 5.5 1995-1999

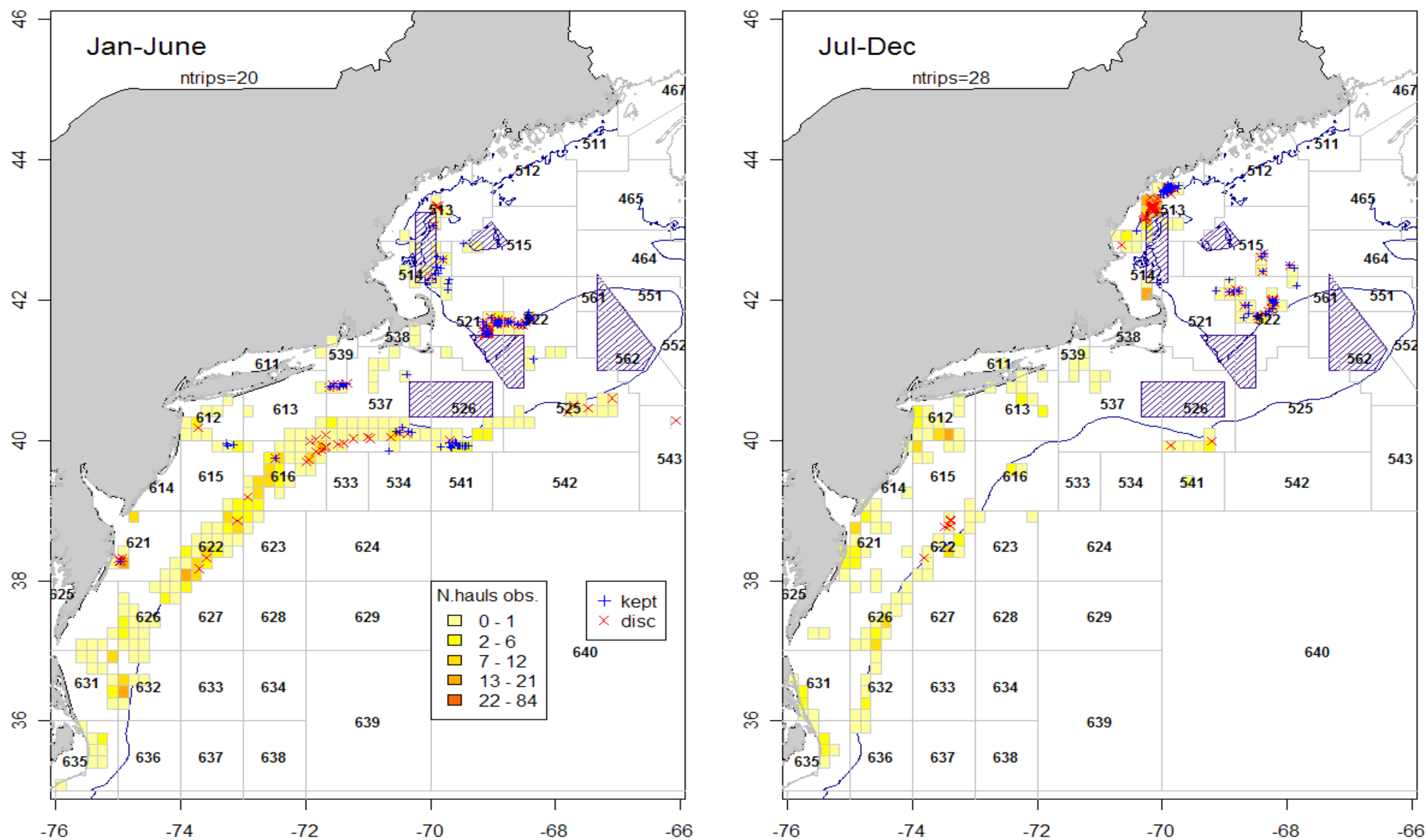


Figure B41. Observed kept and discarded white hake from 1995-1999 in the small-mesh otter trawl fishery.

Observed White Hake Trawl Catches for Mesh Size < 5.5 2001-2005

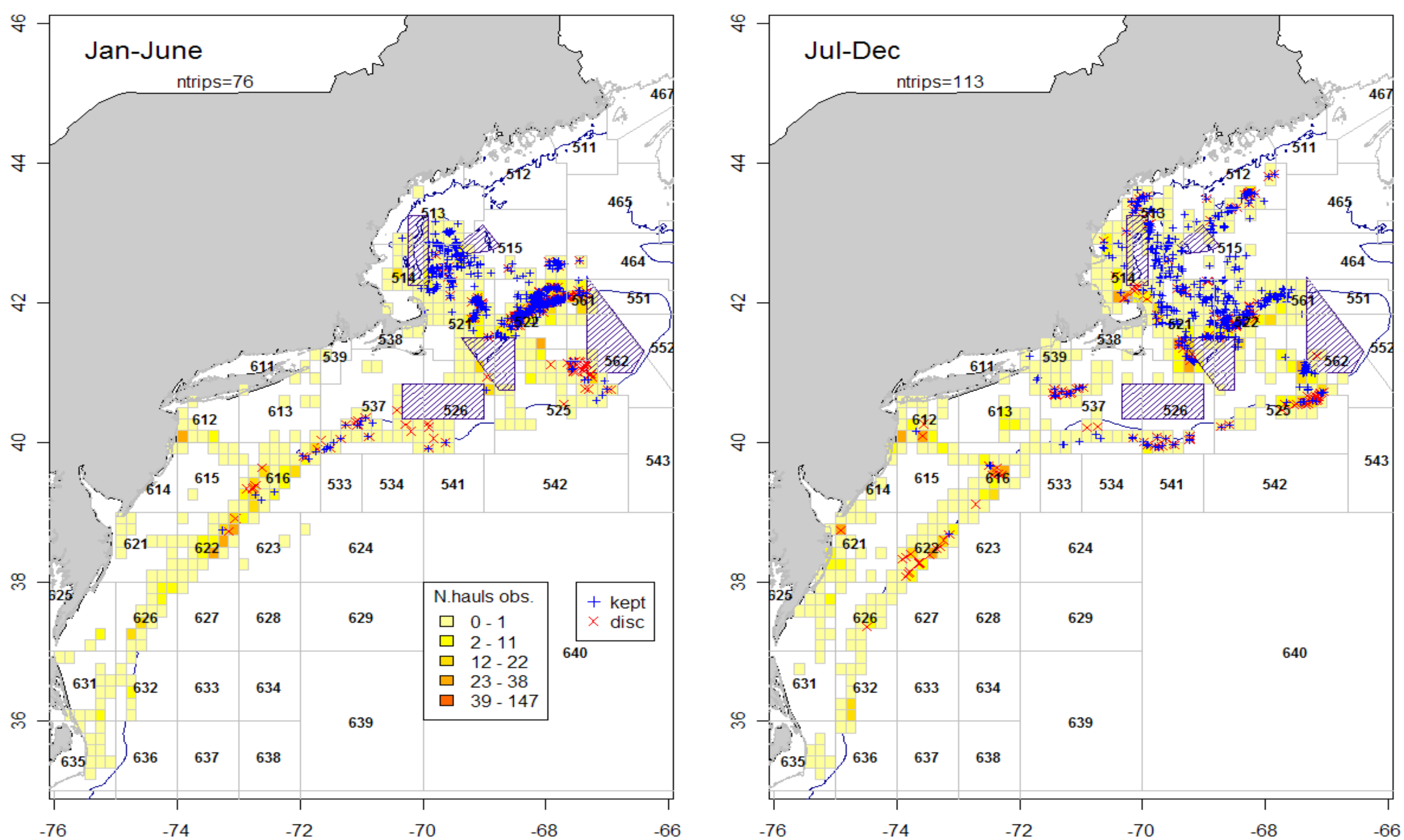


Figure B42. Observed kept and discarded white hake from 2001-2005 in the small-mesh otter trawl fishery.

Observed White Hake Trawl Catches for Mesh Size < 5.5 2007-2011

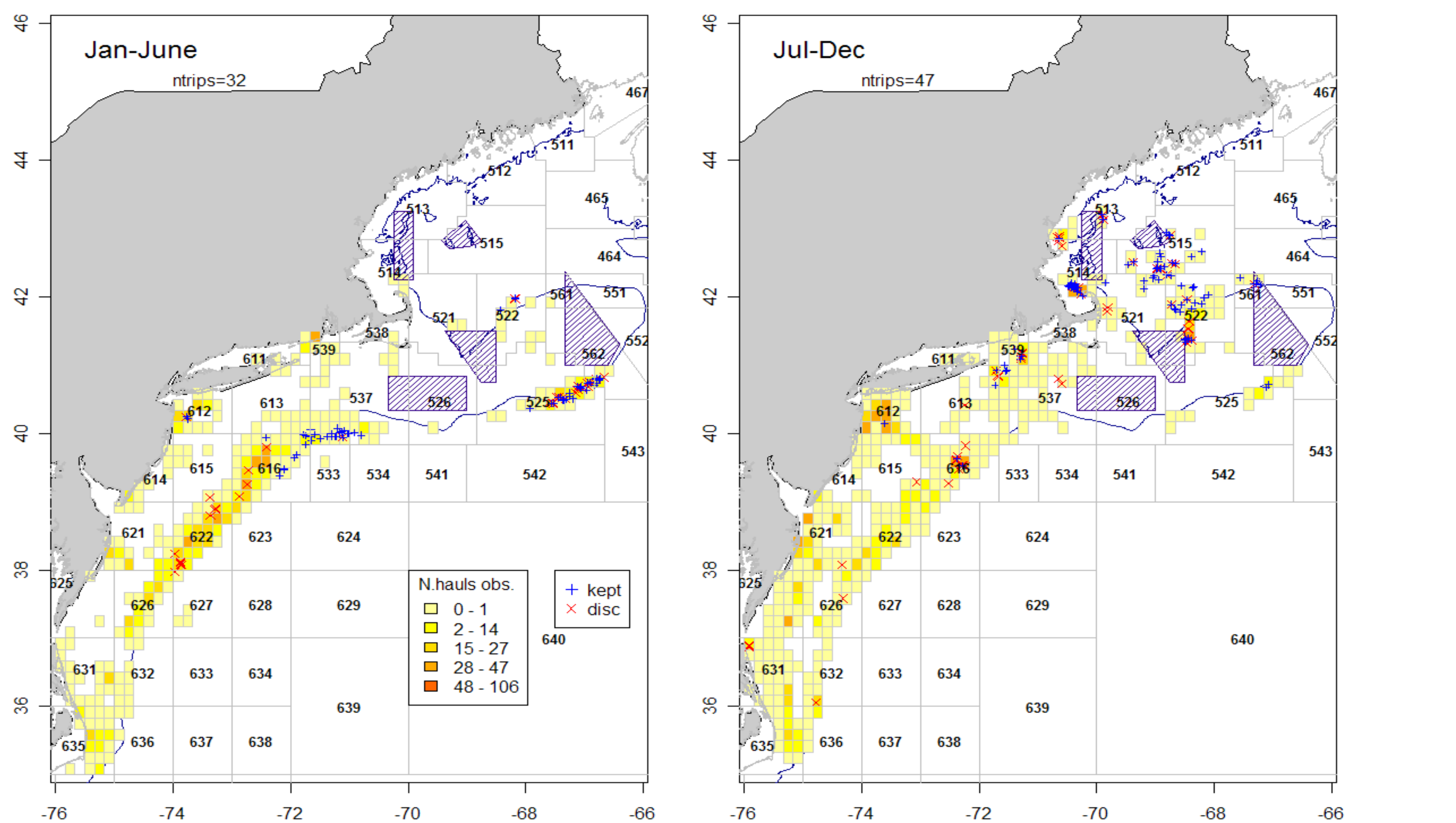


Figure B43. Observed kept and discarded white hake from 2007-2011 in the small-mesh otter trawl fishery.

Observed White Hake Gillnet Catches 1989-1993

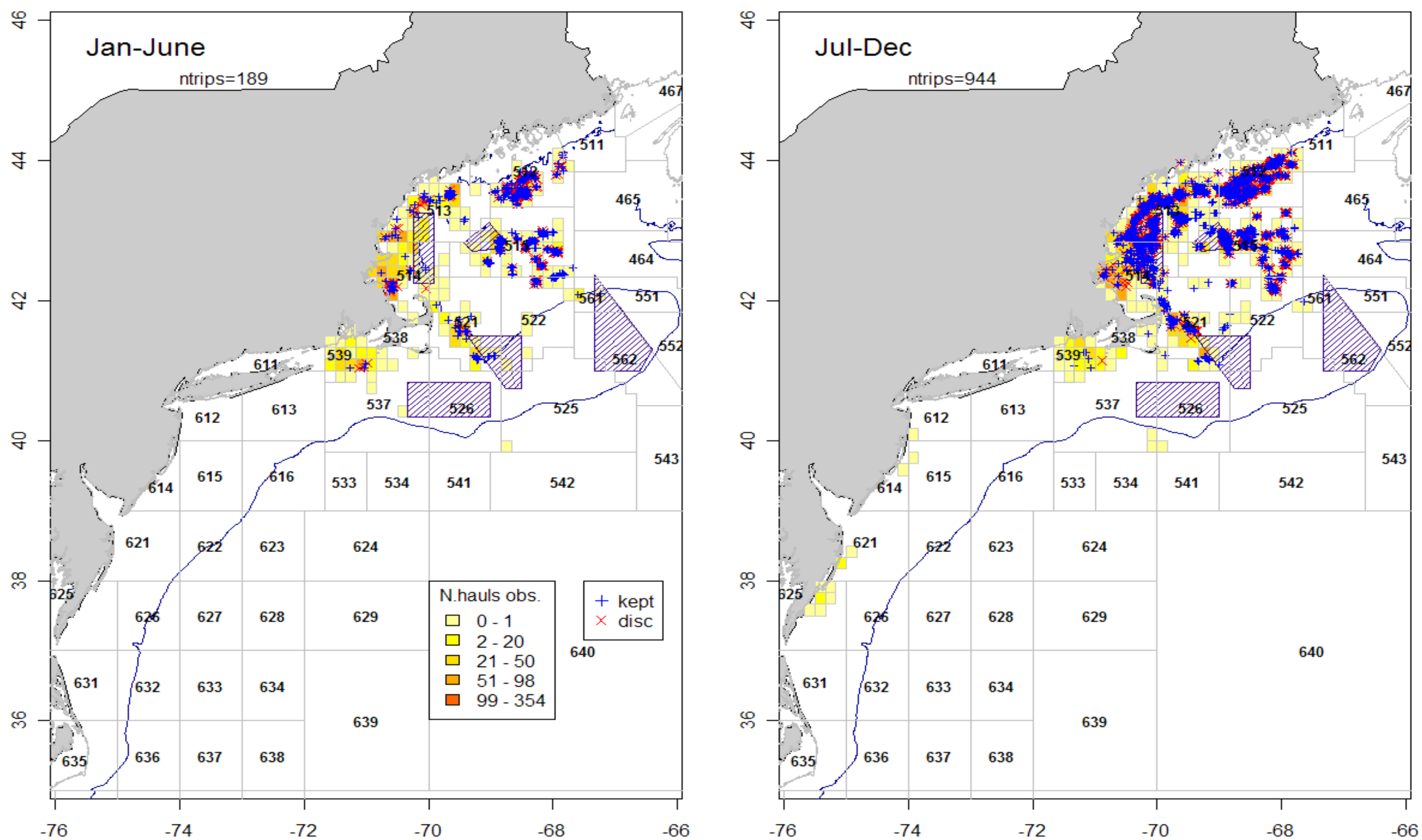


Figure B44. Observed kept and discarded white hake from 1989-1993 in the sink gill net fishery.

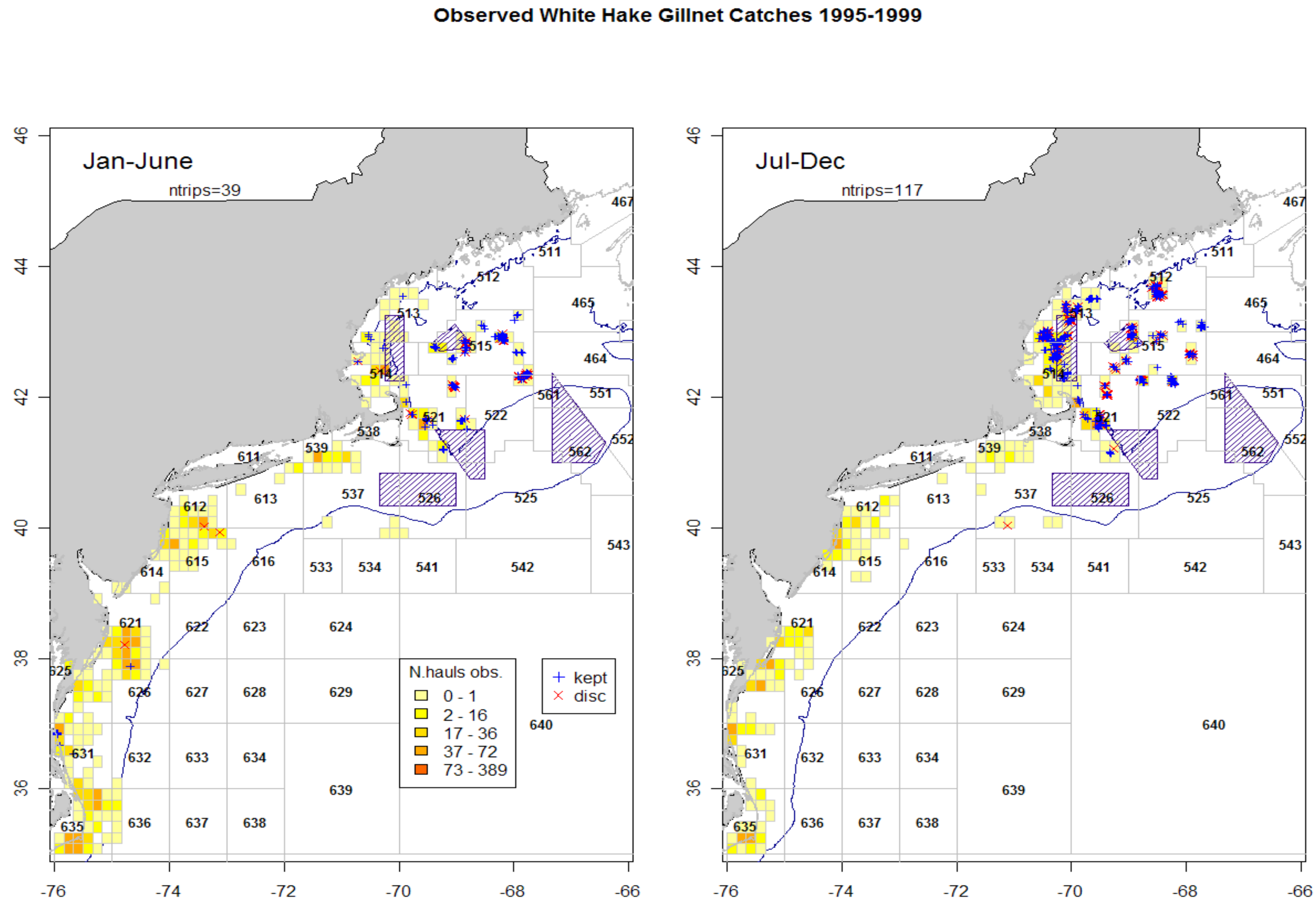


Figure B45. Observed kept and discarded white hake from 1995-1999 in the sink gill net fishery.

Observed White Hake Gillnet Catches 2001-2005

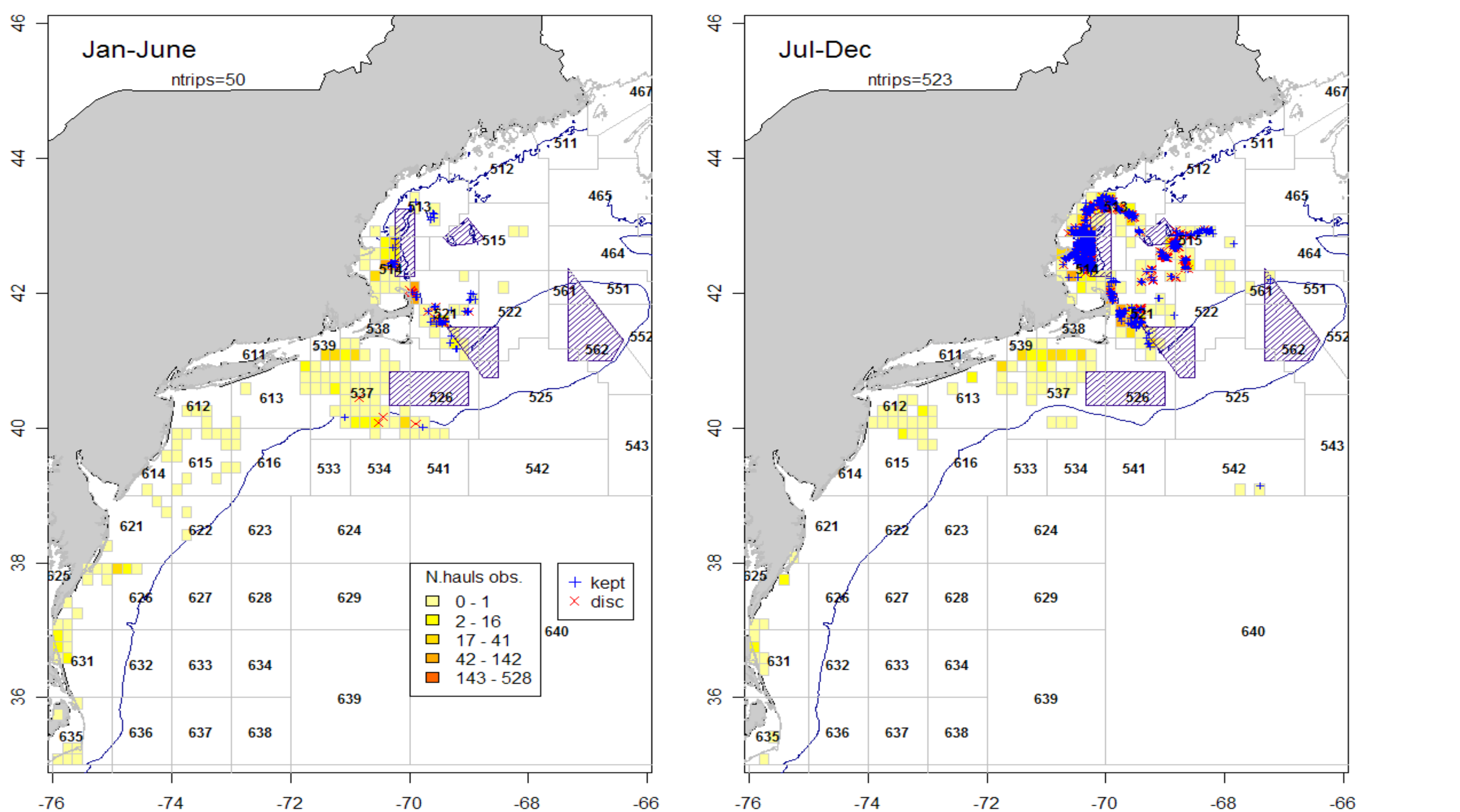


Figure B46. Observed kept and discarded white hake from 2001-2005 in the sink gill net fishery.

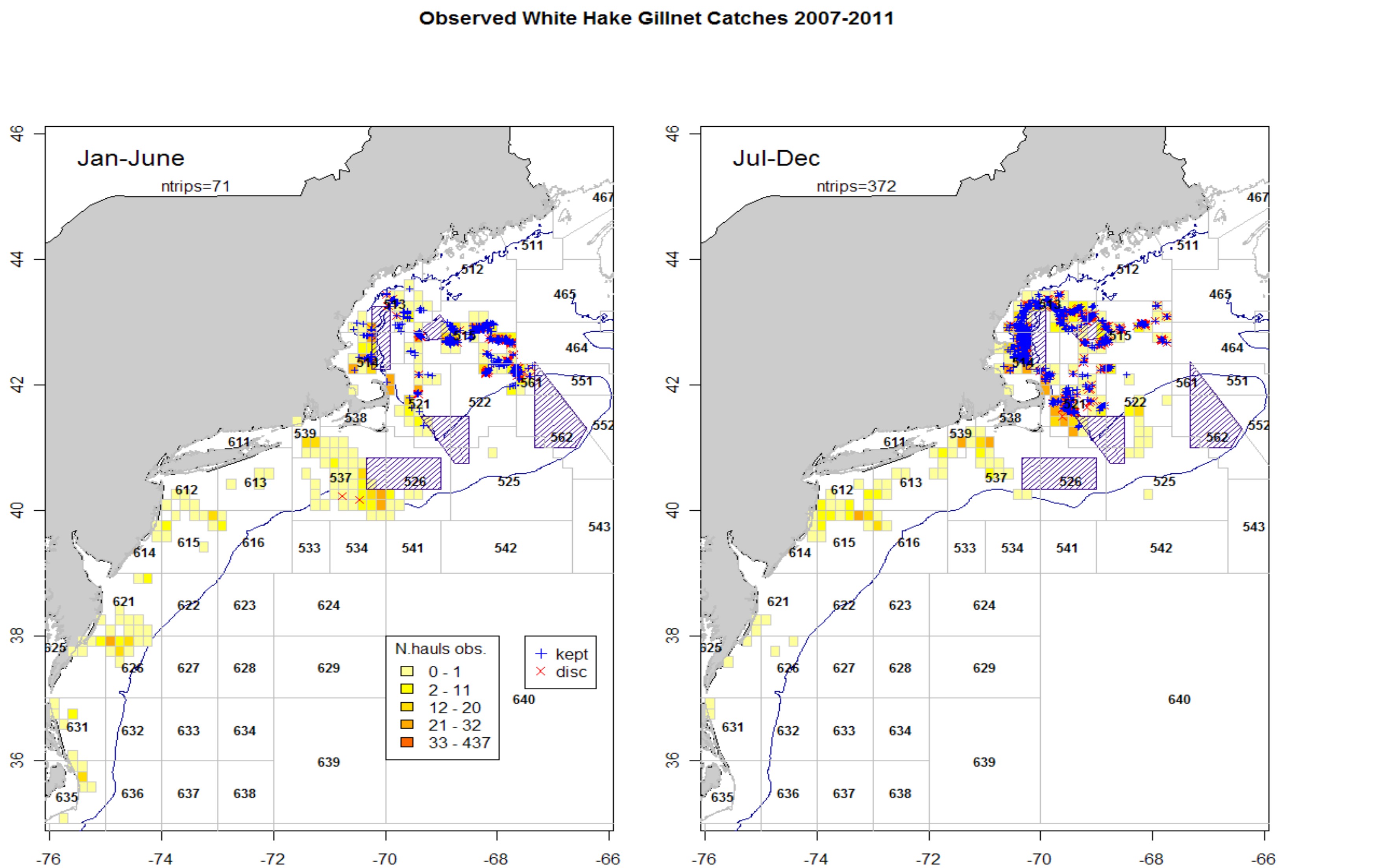


Figure B47. Observed kept and discarded white hake from 2007-2011 in the sink gill net fishery.

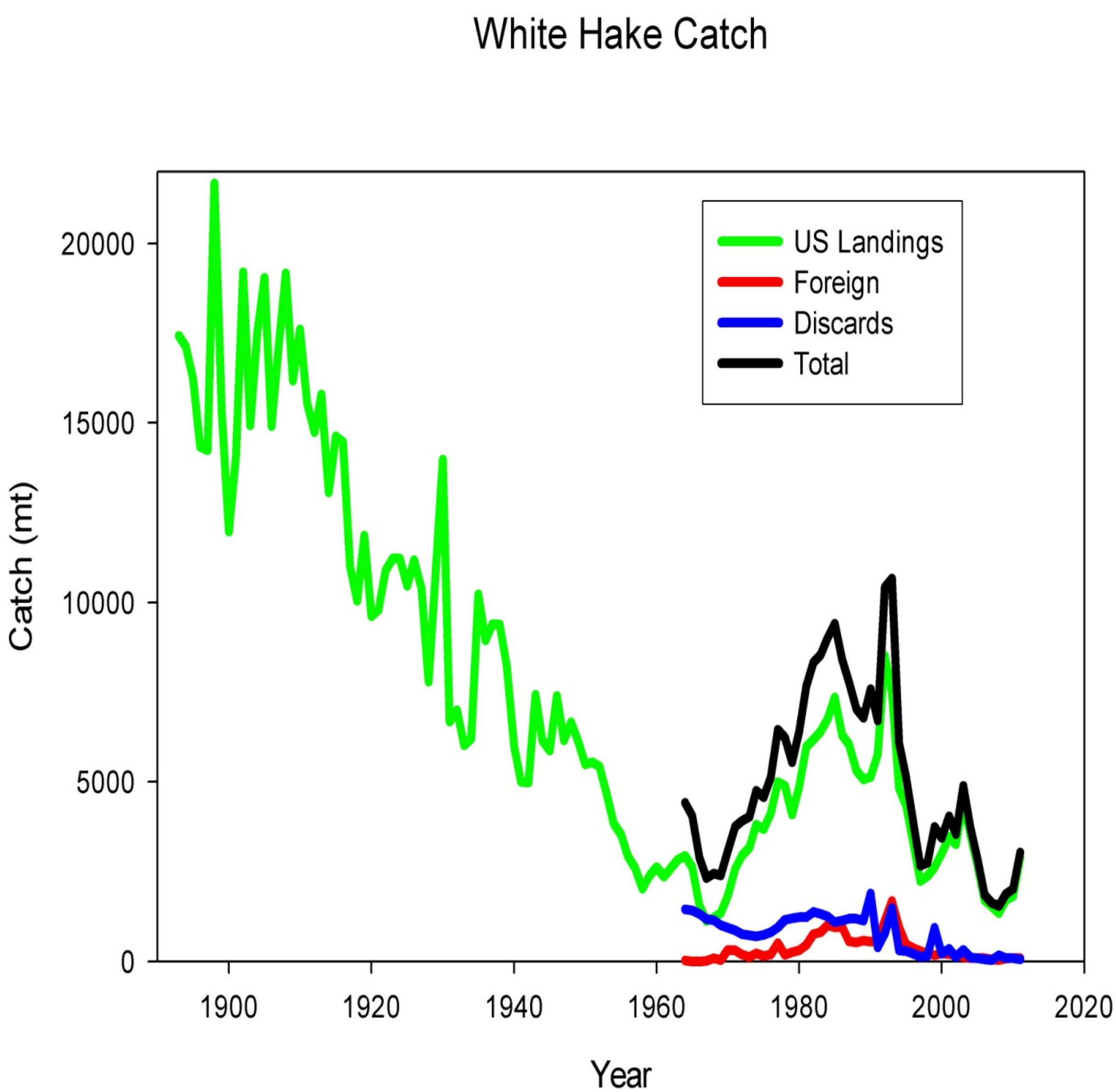


Figure B48. Total catch of white hake. The green line is US landings, the red line is foreign landings and the blue line is US discards. The black line is the total catch from 1964-2011.

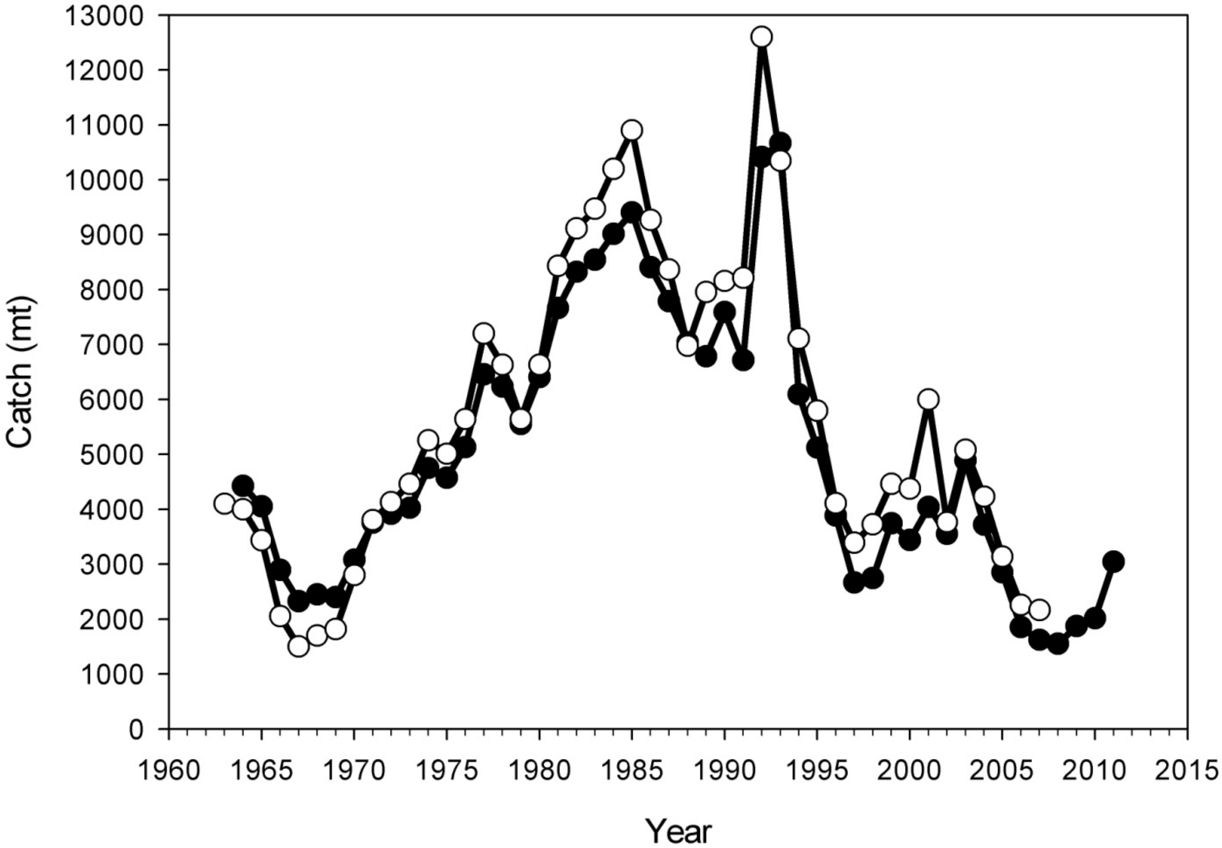


Figure B49. Total catch of white hake estimated in this assessment (filled circles) compared to the estimates of catch from GARM III (open circles).

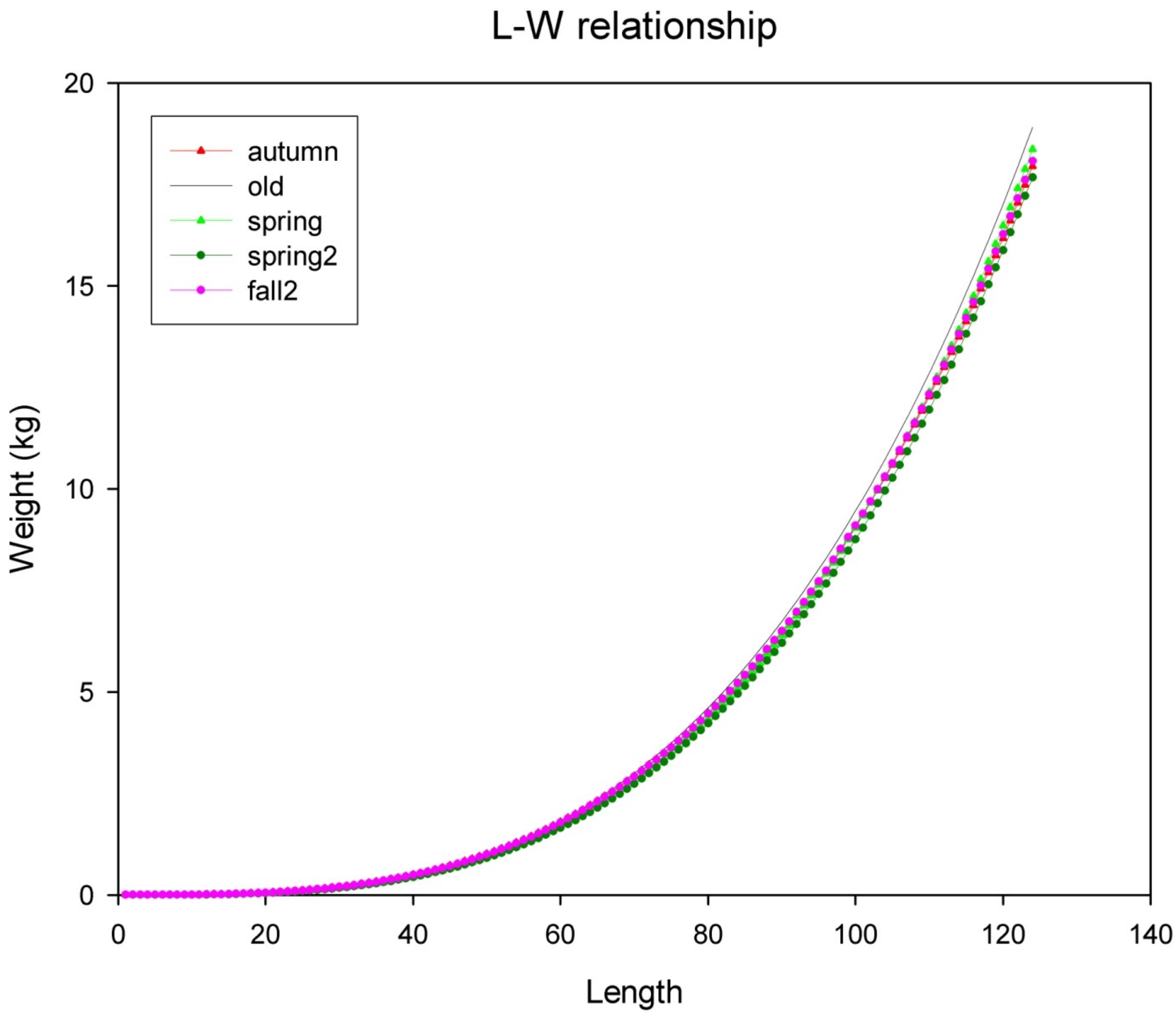


Figure B50. Length-weight relationships of white hake for estimating catch-at-length and catch-at-age. Old is the annual relationship used in the last assessment. Autumn and spring are from Wigley et al (2002). Autumn2 and spring2 have been re-estimated using survey data from 1992-2012.

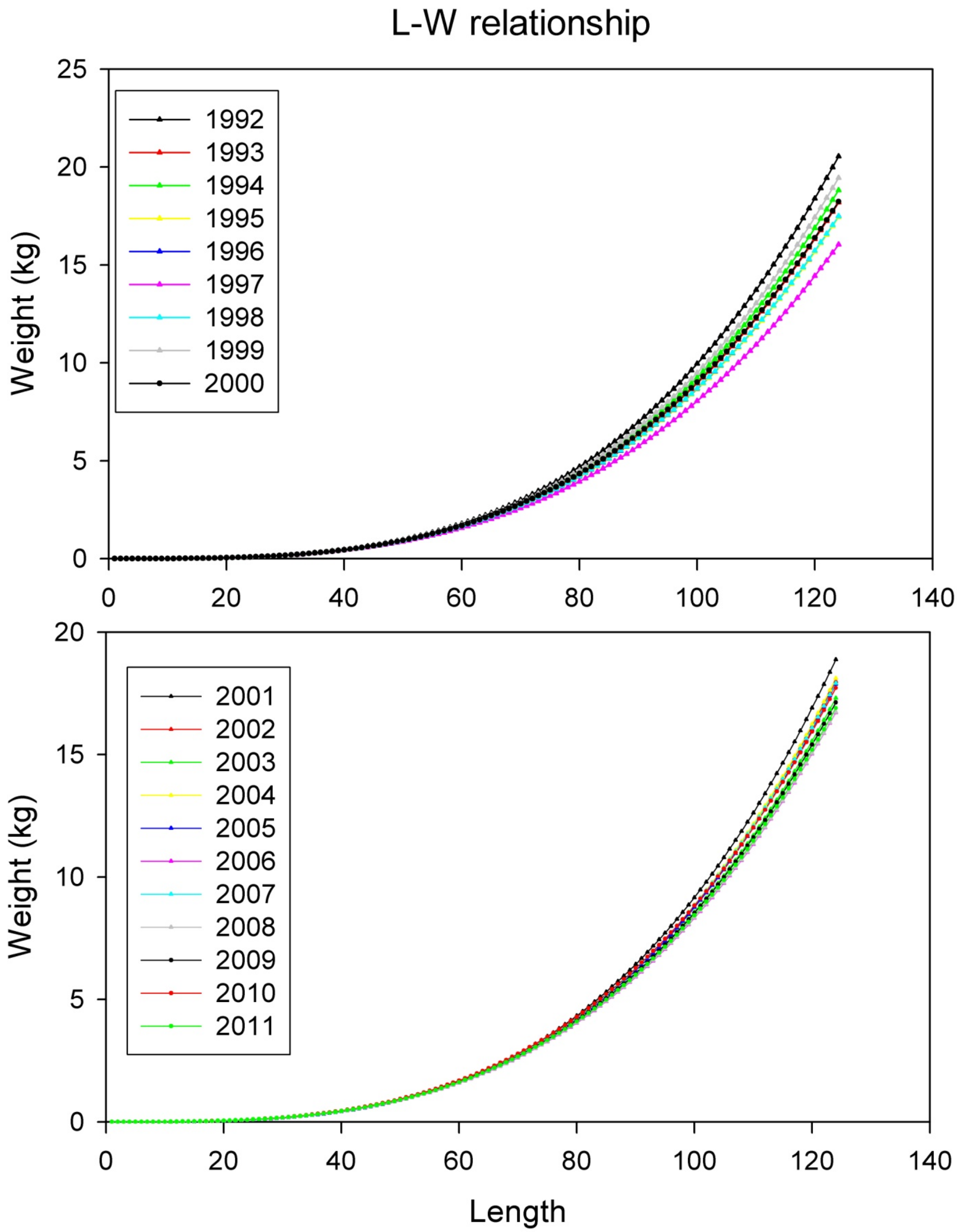


Figure B51. Annual length-weight relationships from the NEFSC spring survey.

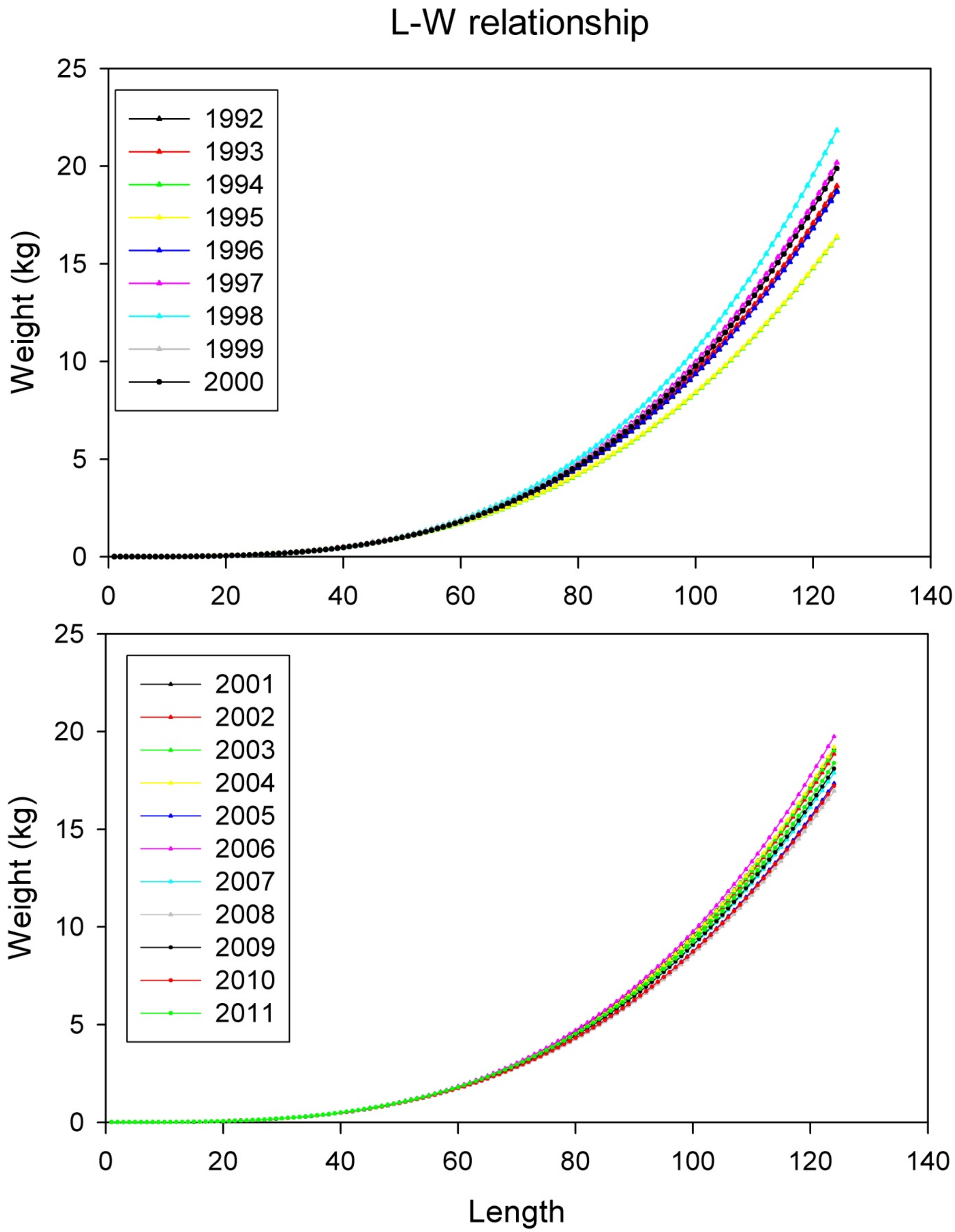


Figure B52. Annual length-weight relationships from the NEFSC fall survey.

Figure B53. Age composition of the landings of white hake. The red bubbles indicate that a pooled ALK was used.

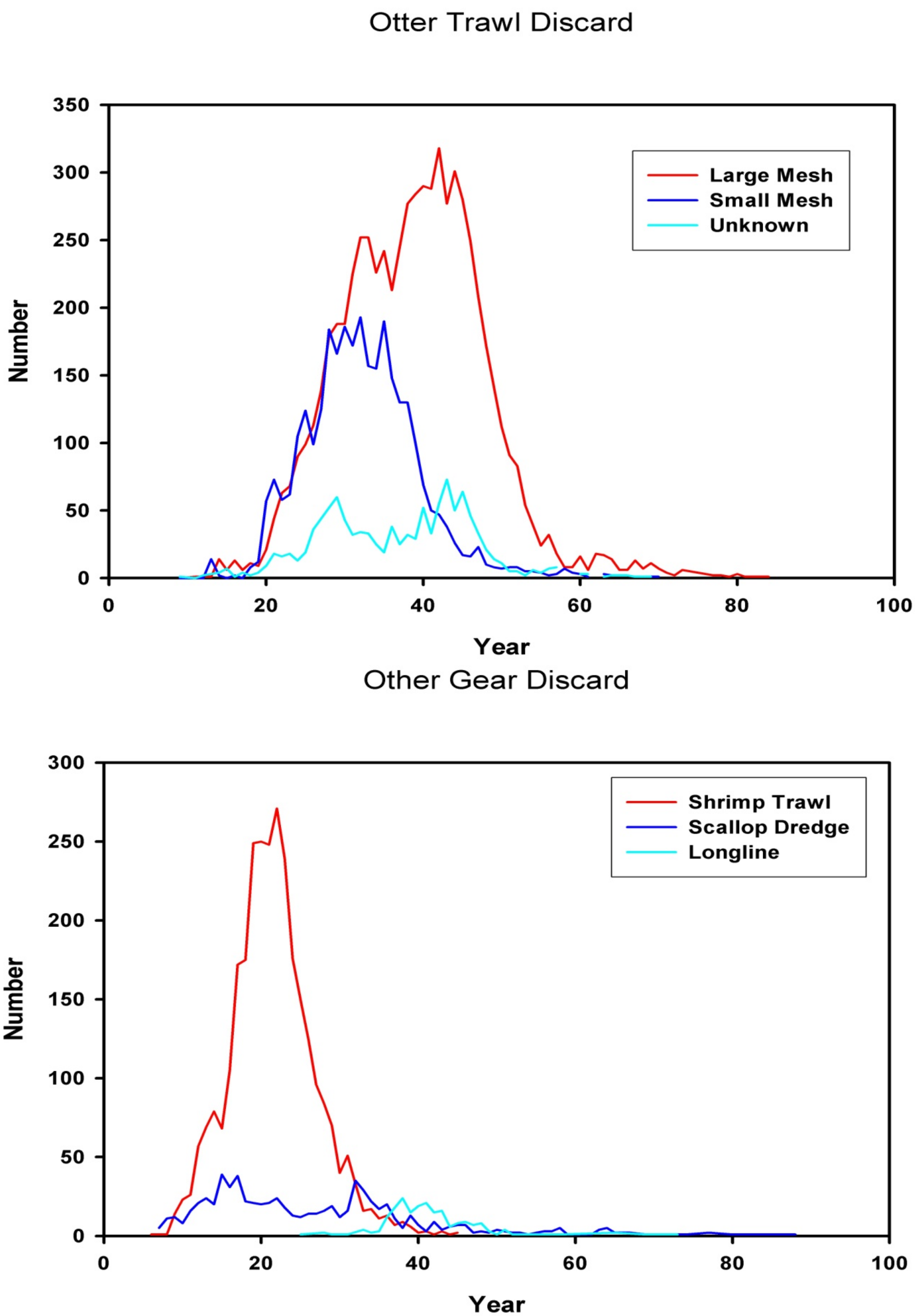


Figure B54. Length composition of discarded white hake from the otter trawl fishery (top panel) and other gear types (bottom panel).

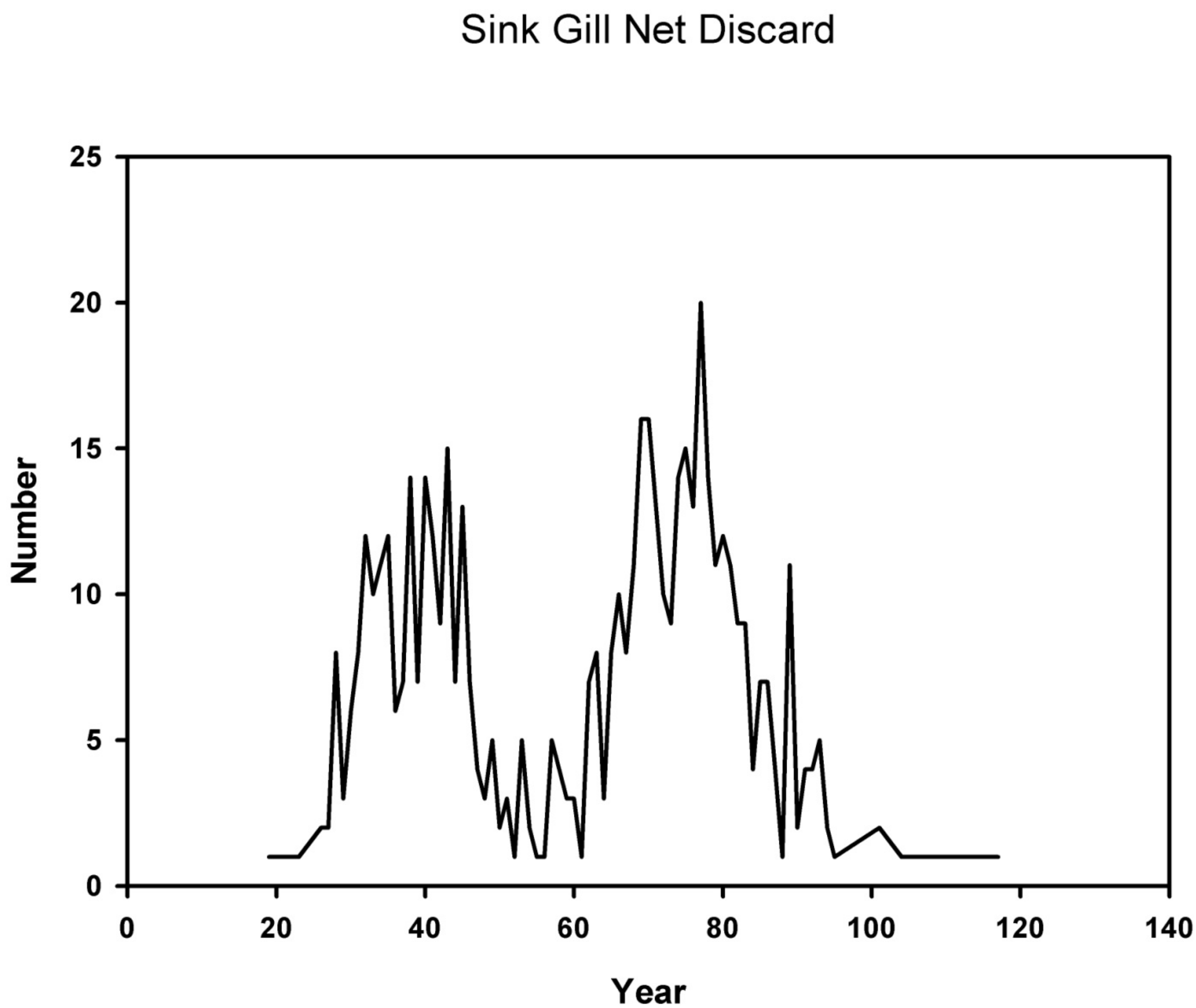


Figure B55. Length composition of white hake discarded in the sink gill net fishery.

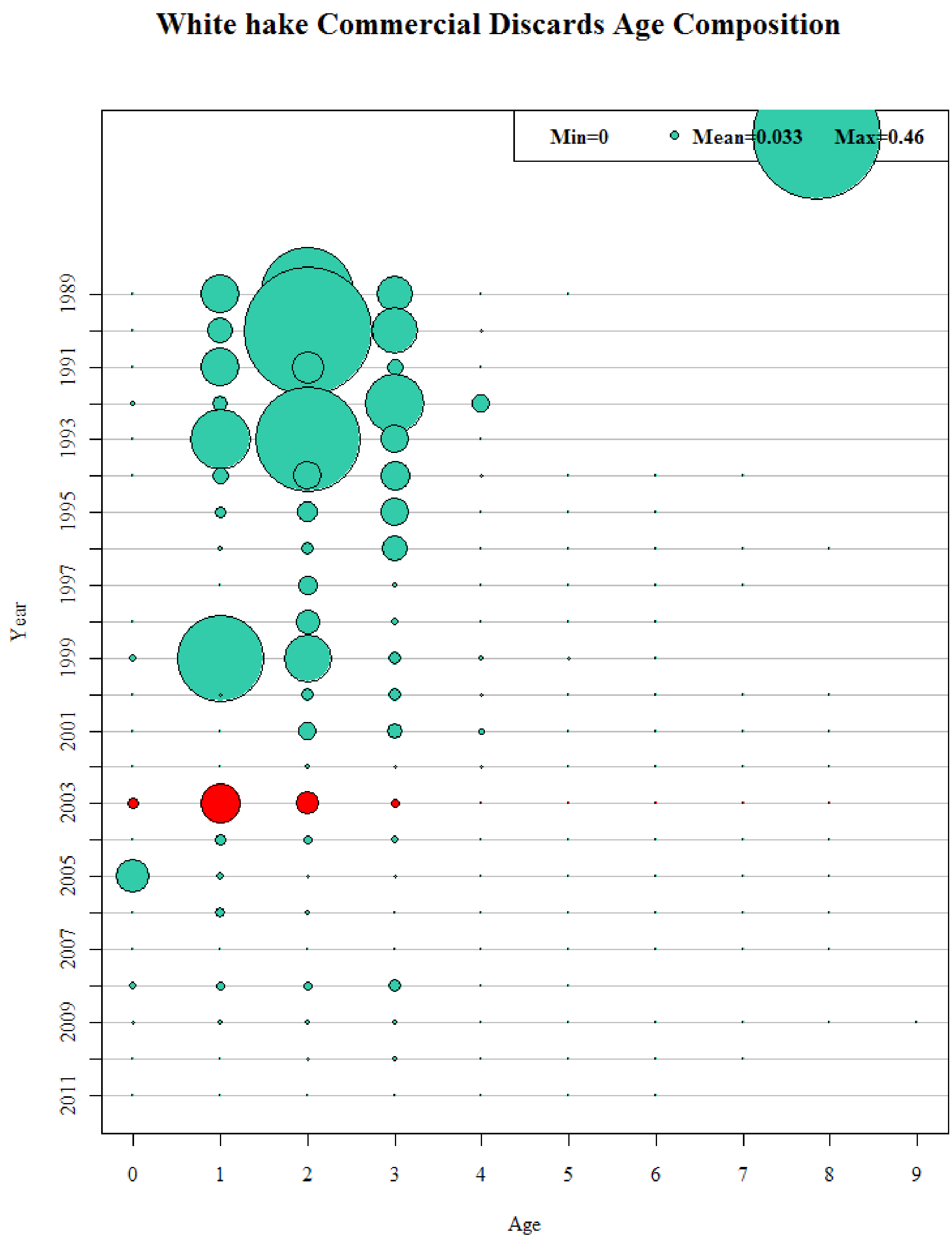


Figure B56. Age composition of the discards of white hake. The red bubbles indicate that a pooled ALK was used.

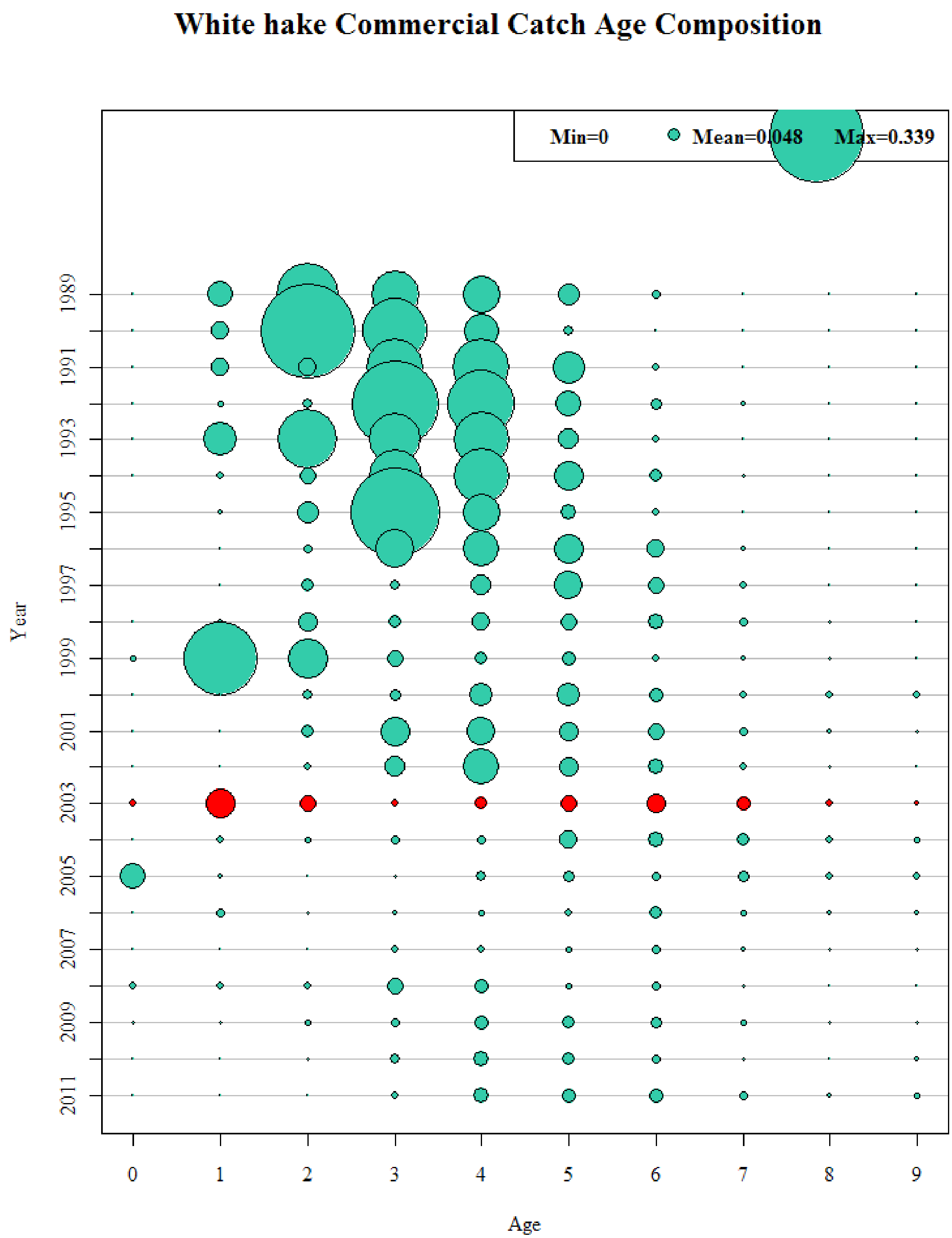


Figure B57. Age composition of the catch of white hake. The red bubbles indicate that a pooled ALK was used.

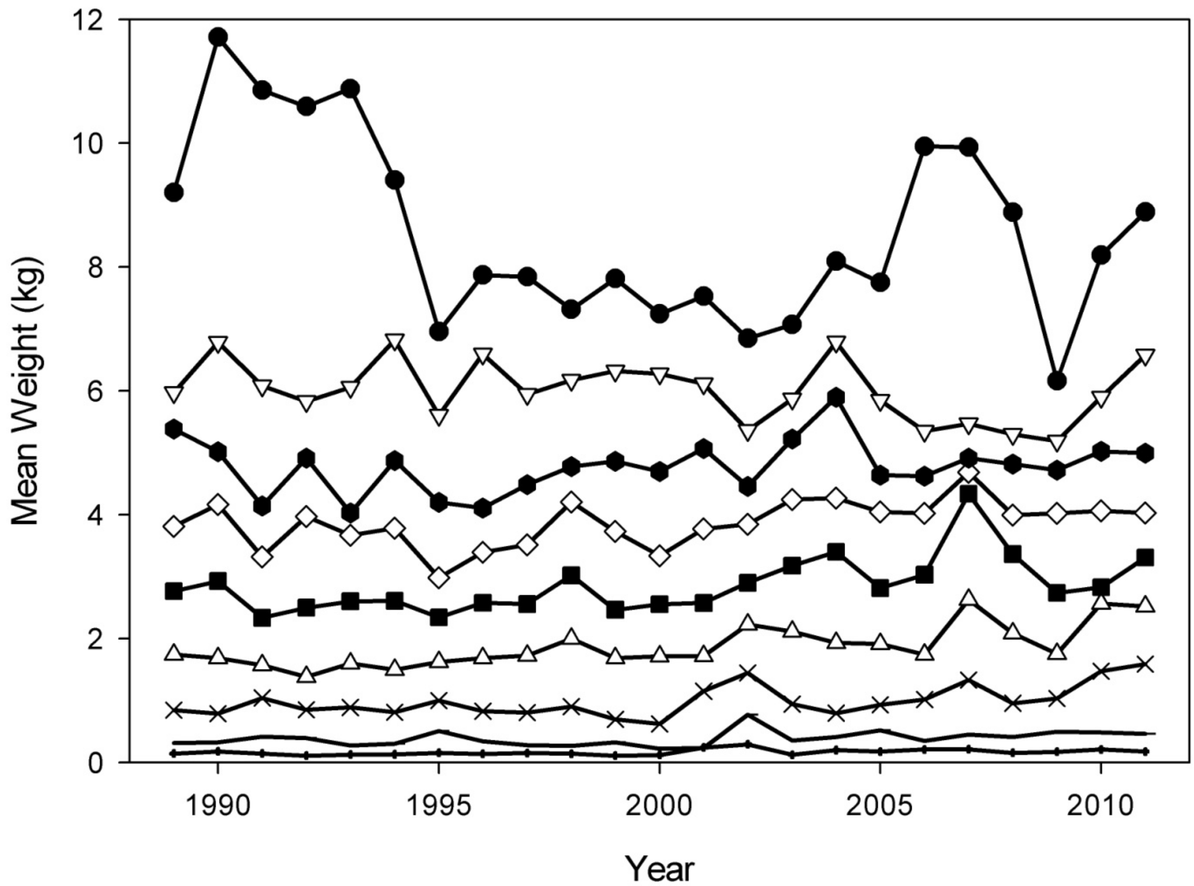


Figure B58. Mean weight-at-age of the white hake catch.

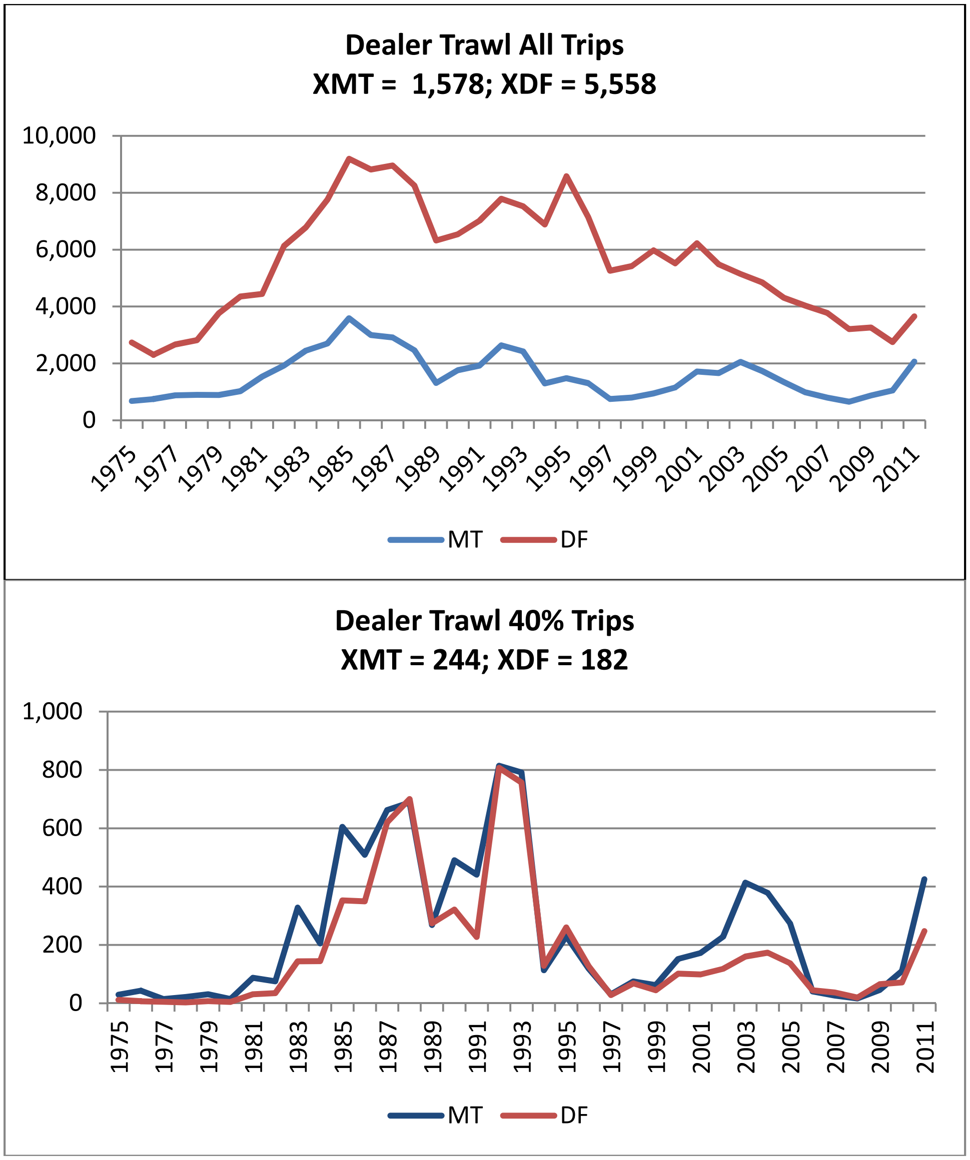


Figure B59. Summary of commercial dealer trawl landings, days fished, and nominal LPUE. The top Panel is All Trips (100% of Landings, 100% of DF). The bottom Panel is trips that land more than 40% white hake (Over time series, 15% of Mean Annual Landings, 3% of Mean Annual DF).

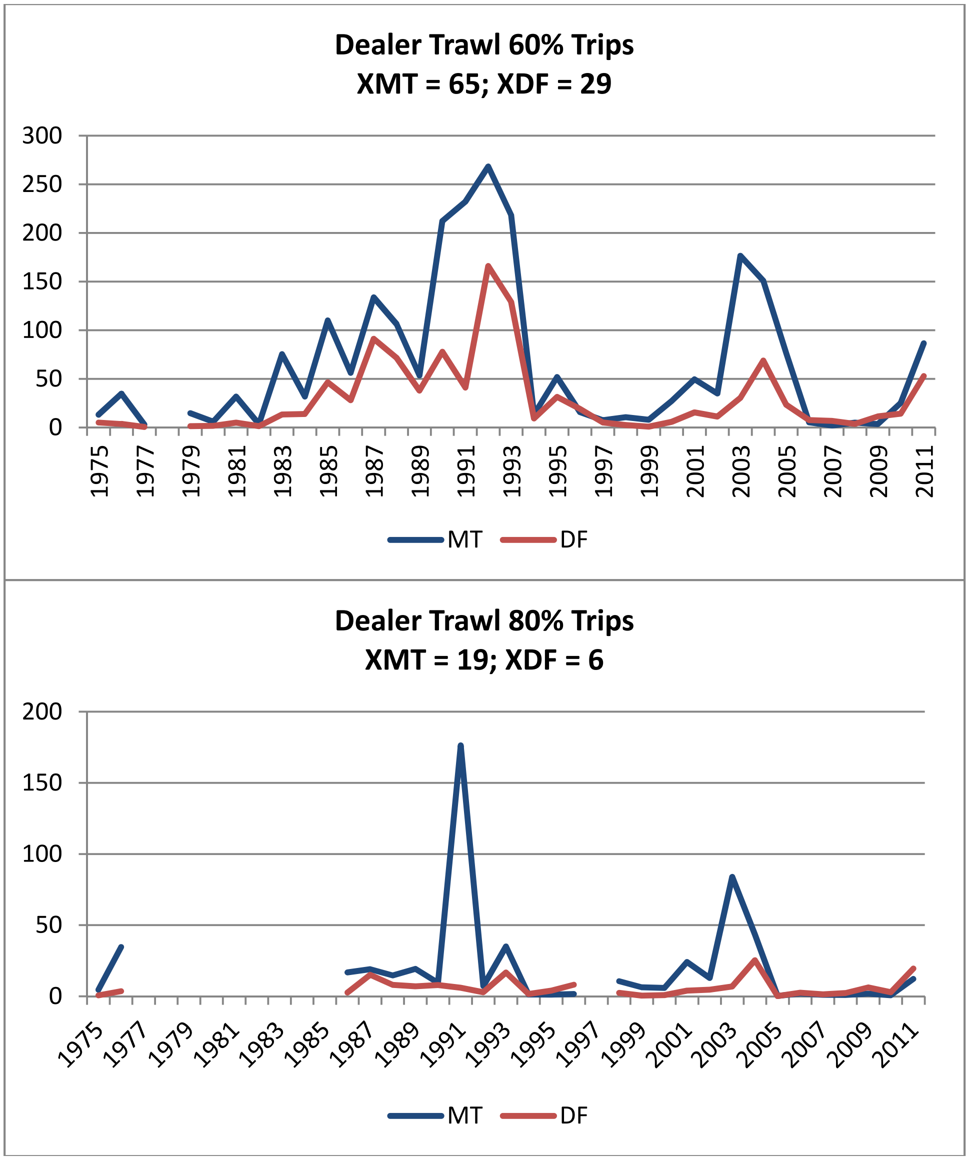


Figure B60. Summary of commercial dealer trawl landings, days fished, and nominal LPUE. The top Panel is trips that landed over 60% white hake (Over time series, 4% of Mean Annual Landings, 1% of Mean Annual DF). The bottom panel is trips that landed over 80% white hake (Over time series, 1% of Mean Annual Landings, 0.1% of Mean Annual DF).

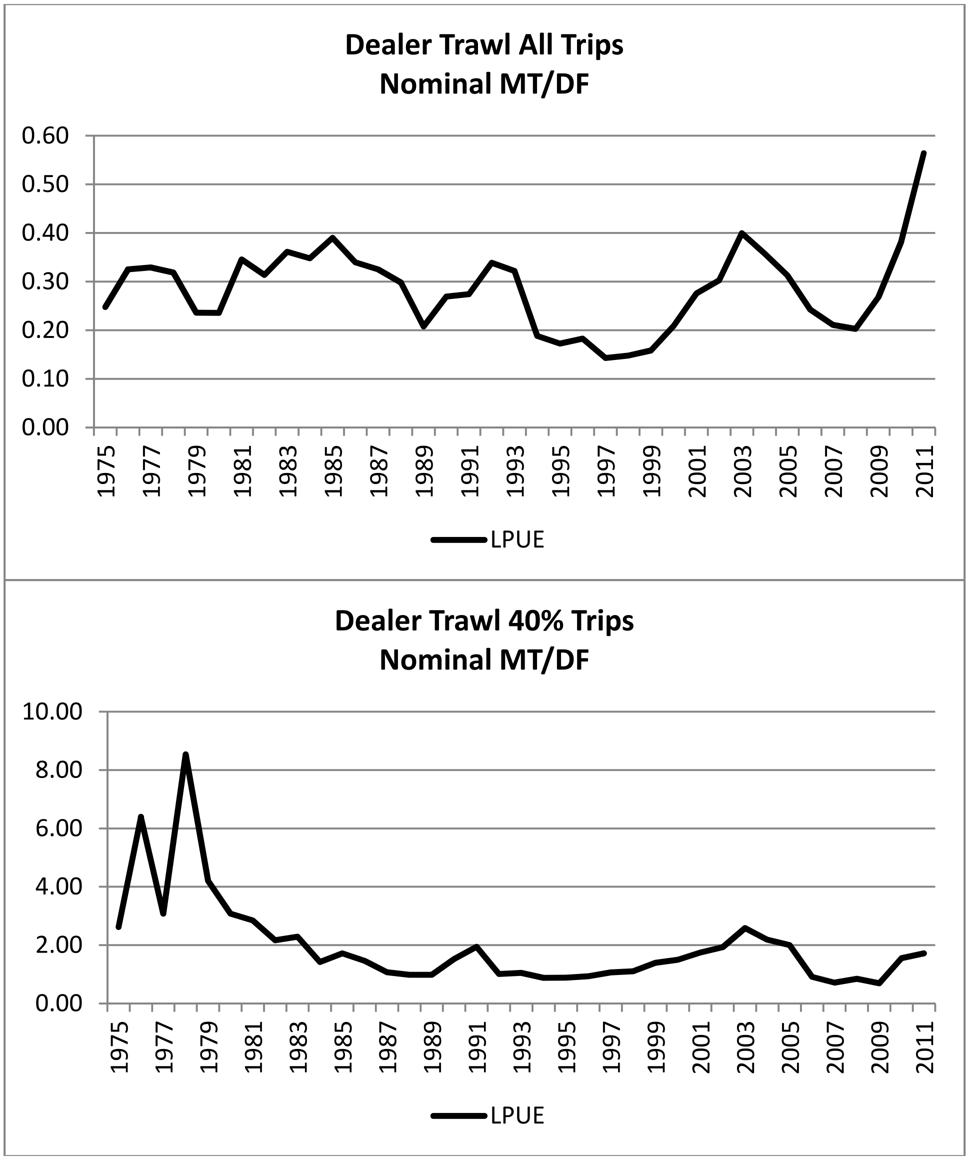


Figure B61. Nominal LPUE (mt/df) from all otter trawl trips (top panel) and otter trawl trips in which white hake accounted for 40% of the catch (bottom panel).

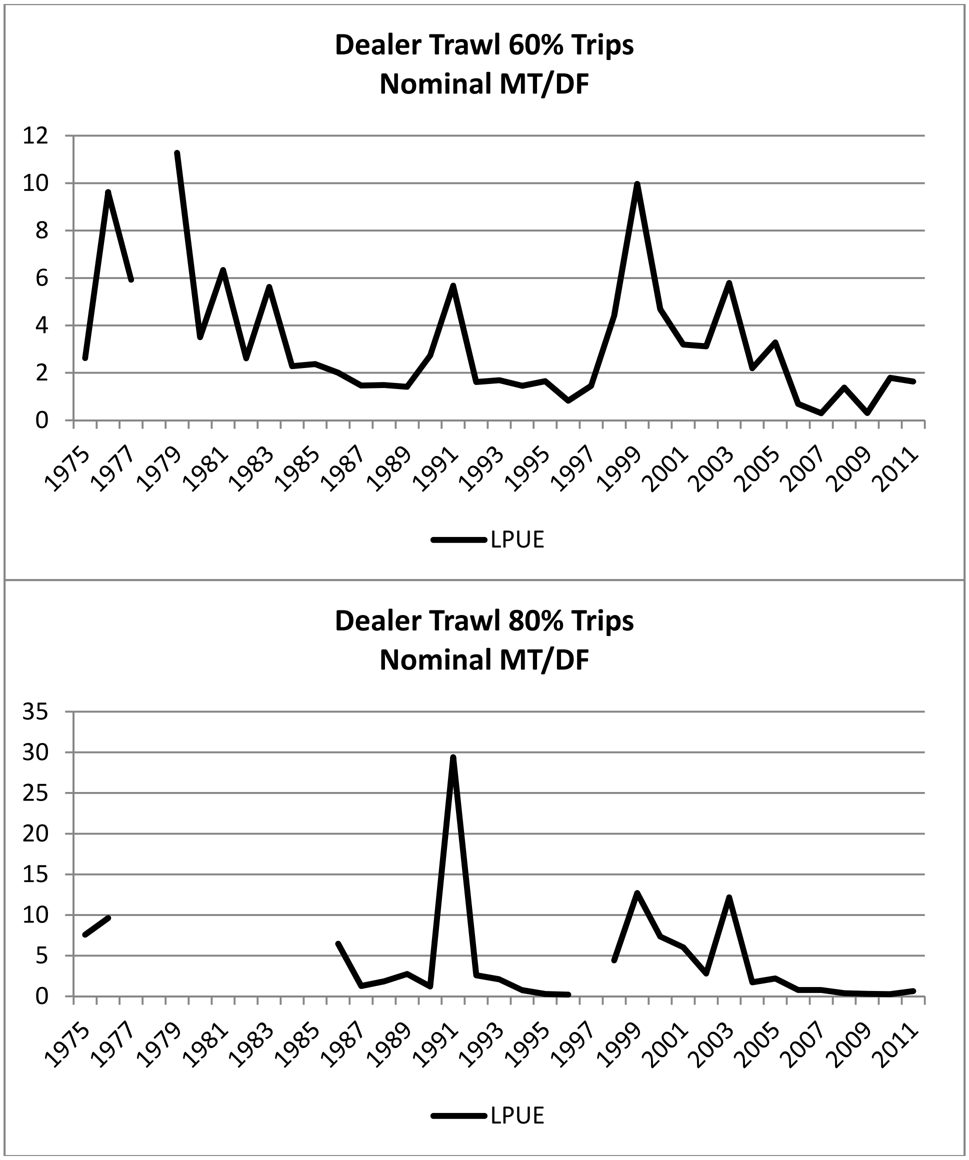


Figure B62. Nominal LPUE (mt/df) from otter trawl trips in which white hake accounted for 60% of the catch (top panel) and otter trawl trips in which white hake accounted for 80% of the catch (bottom panel).

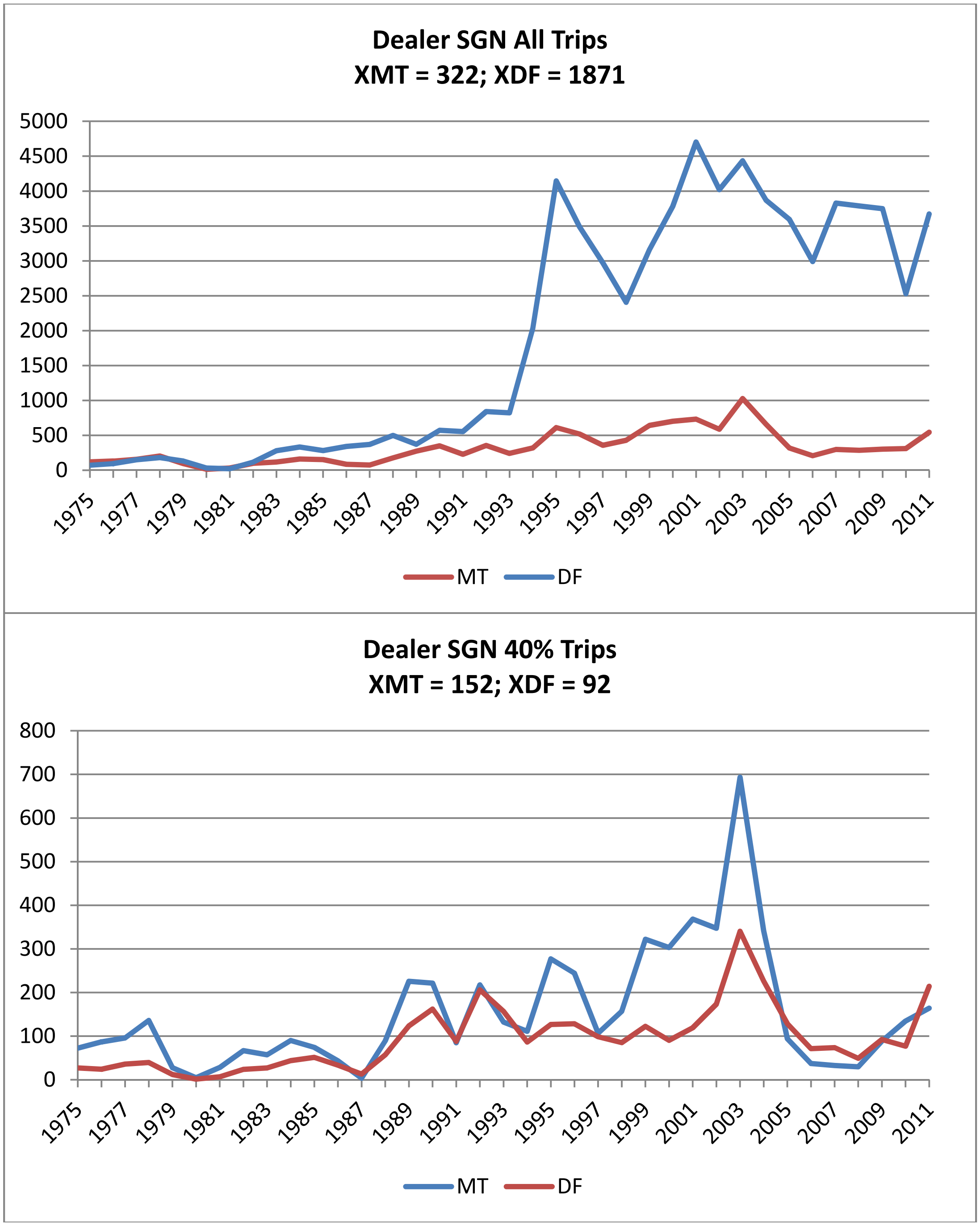


Figure B63. Summary of commercial dealer sink gill net landings, days fished, and nominal LPUE. The top Panel is All Trips (100% of Landings, 100% of DF). The bottom Panel is trips that land more than 40% white hake (Over time series, 47% of Mean Annual Landings, 5% of Mean Annual DF, Over1994-2011, 3% of Mean Annual DF).

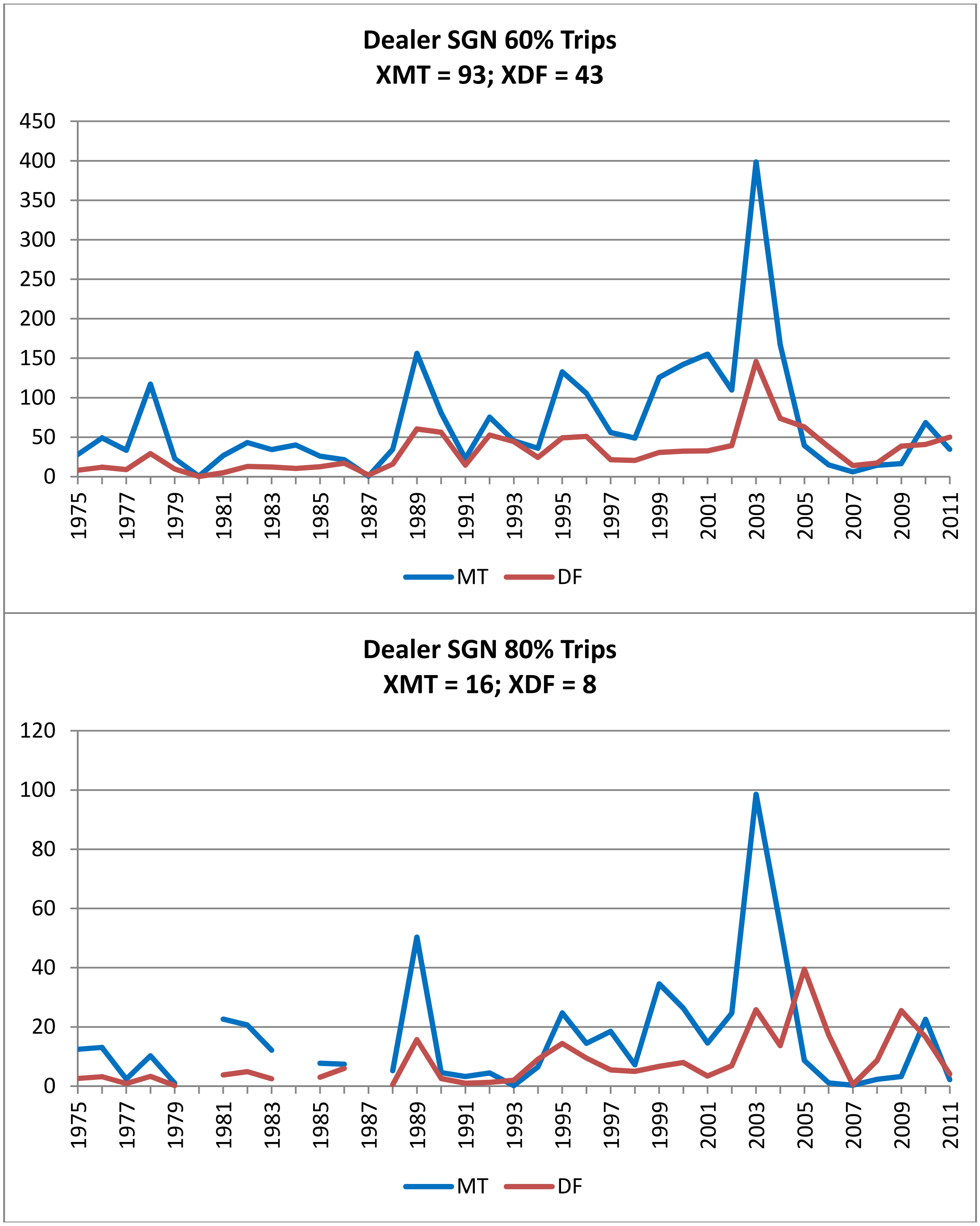


Figure B64. Summary of commercial dealer sink gill net landings, days fished, and nominal LPUE. The top Panel is trips that land more than 60% white hake (Over time series 29% of Mean Annual Landings, 2% of Mean Annual DF; Over 1994-2011, 1% of Mean Annual DF). The bottom Panel is trips that land more than 80% white hake (Over time series, 5% of Mean Annual Landings, 0.4 % of Mean Annual DF; Over 1994-2011, 0.3% of Mean Annual DF).

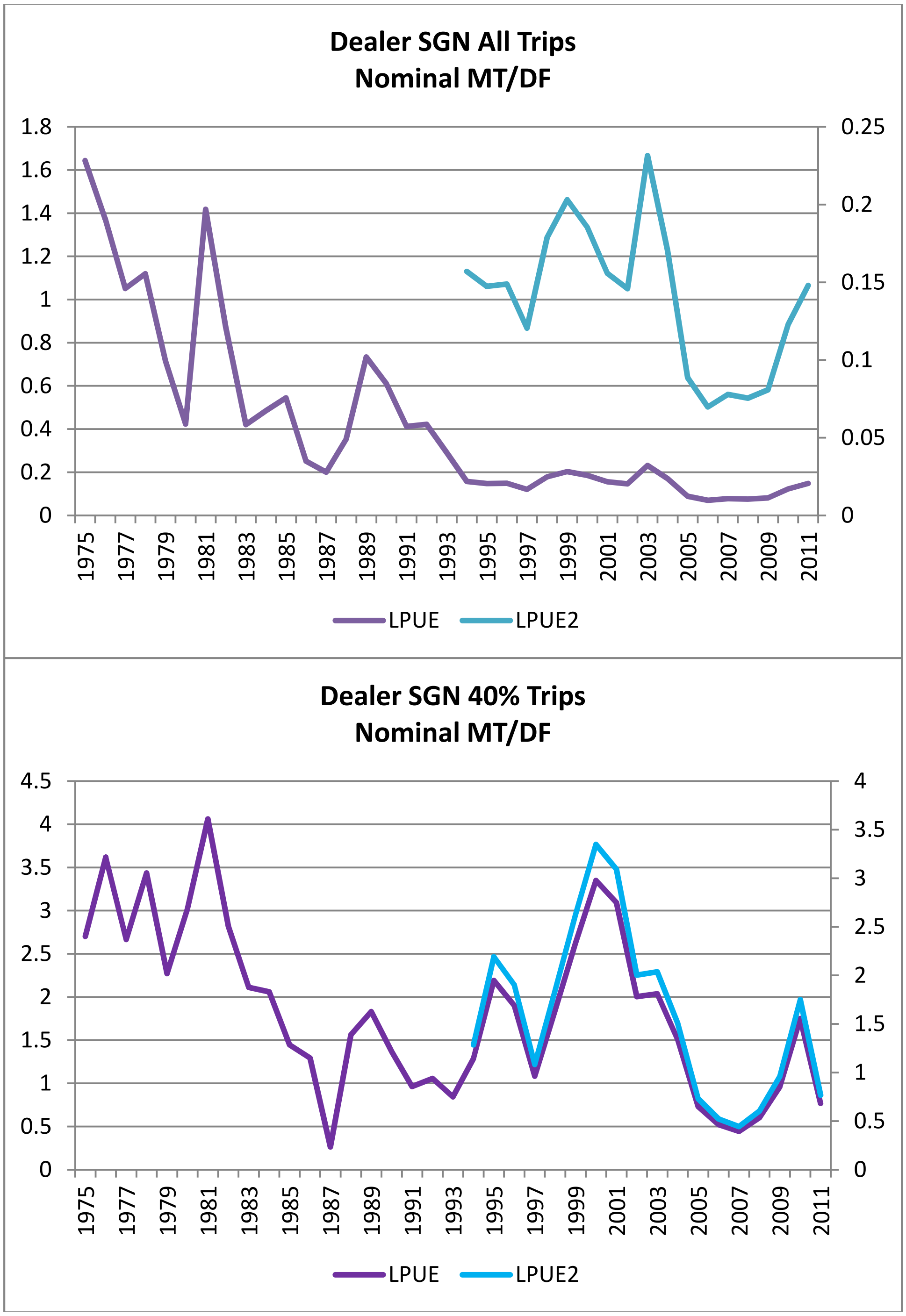
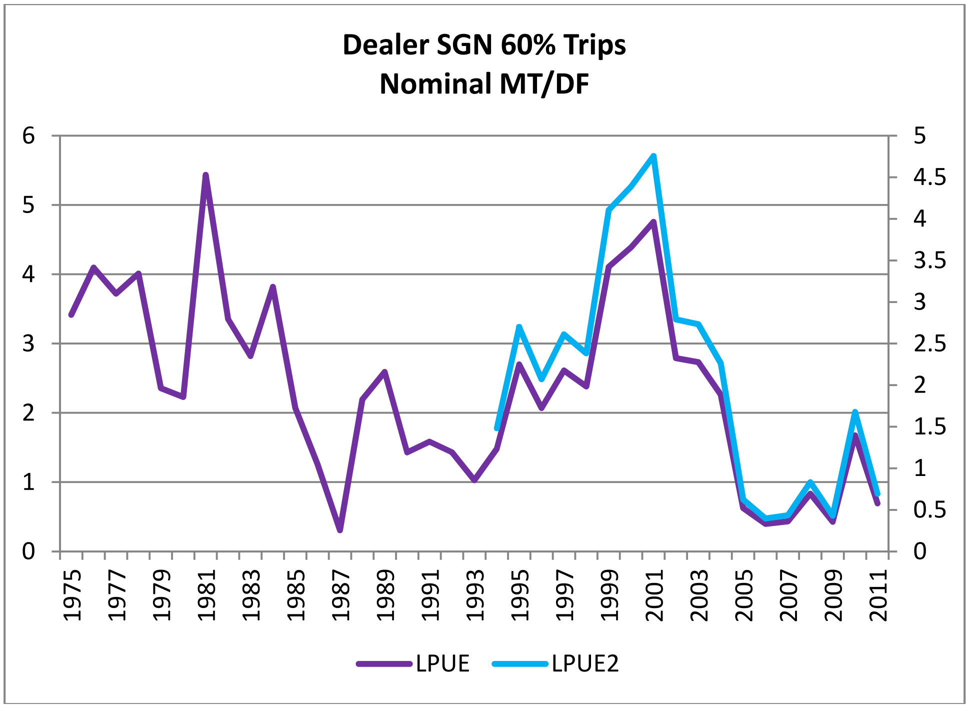


Figure B65. Nominal LPUE (mt/df) from all sink gill net trips (top panel) and sink gill net trips in which white hake accounted for 40% of the catch (bottom panel). The blue line is the LPUE scaled for only 1994-2011, since there may be a change in the way effort was calculated starting in 1994.



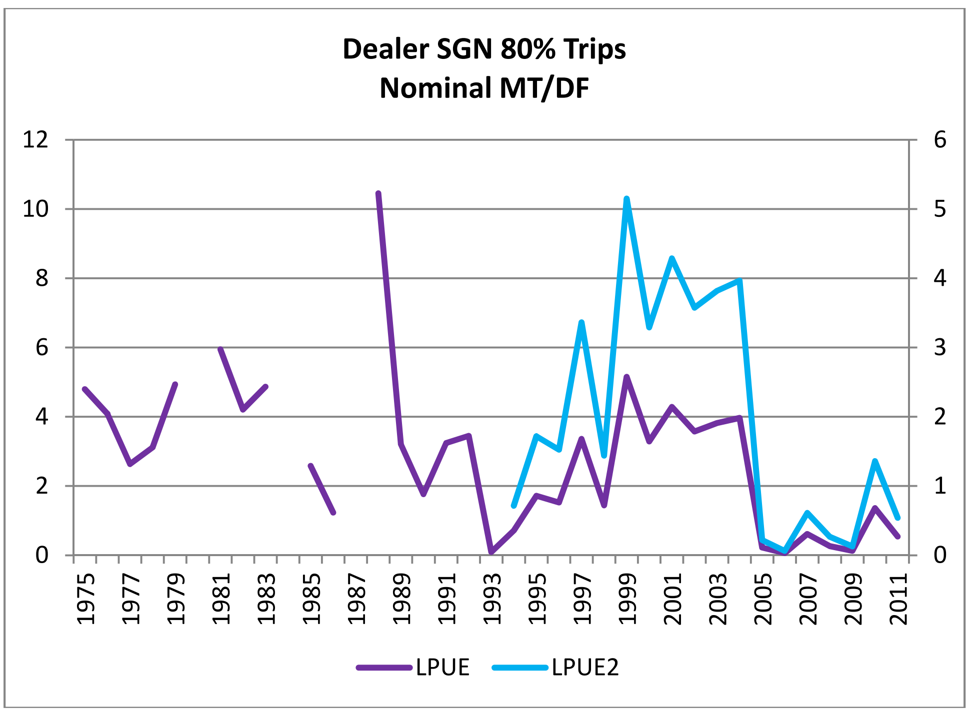


Figure B66. Nominal LPUE (mt/df) from sink gill net trips in which white hake accounted for 60% of the catch (top panel) and sink gill net trips in which white hake accounted for 80% of the catch (bottom panel). The blue line is the LPUE scaled for only 1994-2011, since there may be a change in the way effort was calculated starting in 1994.

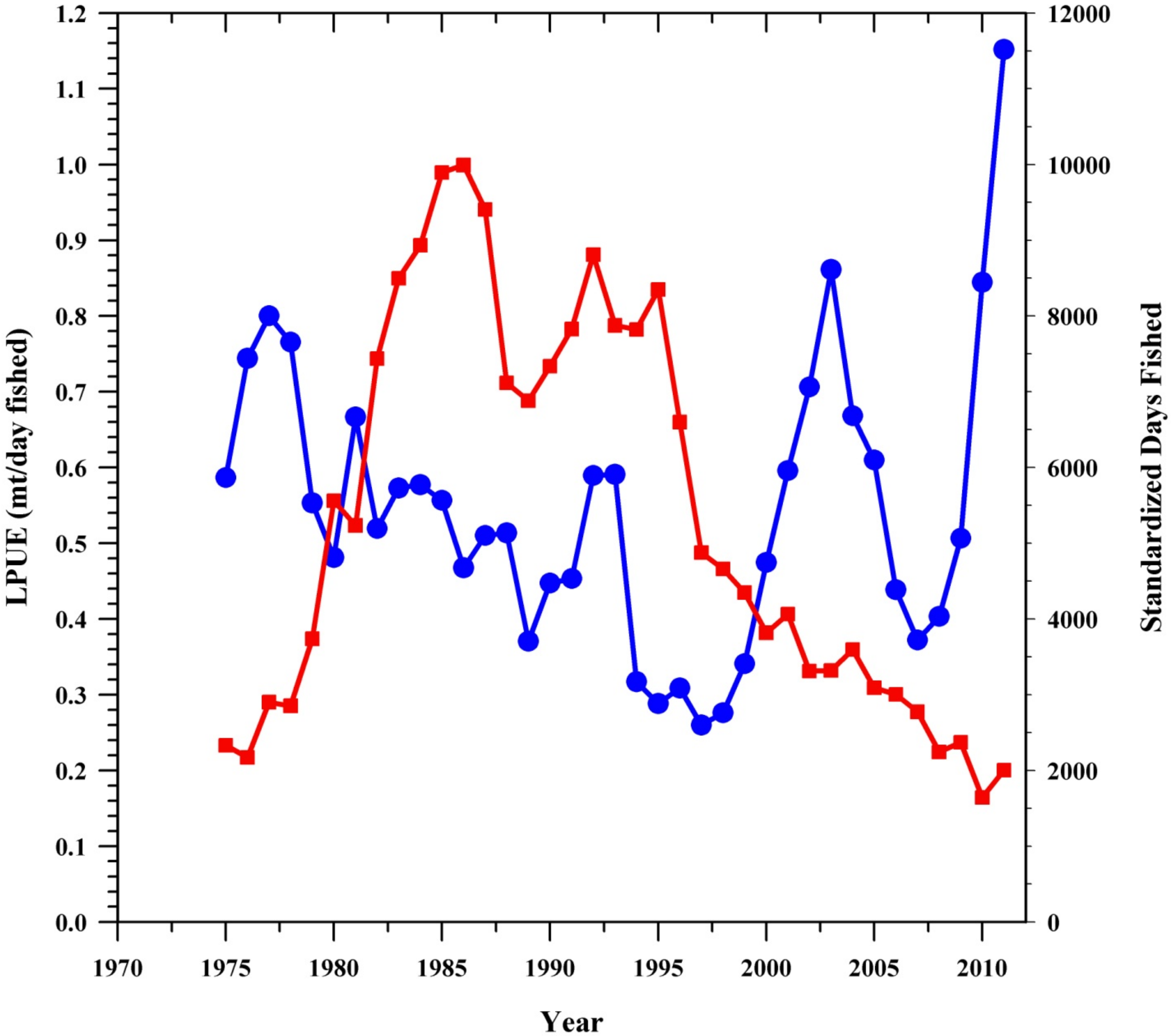


Figure B67. Standardized landings per day fished (LPUE, circles) and effort (days fished raised to total otter trawl landings, solid line) of all white hake trips using a general linear model: year, quarter, area, and tonnage class.

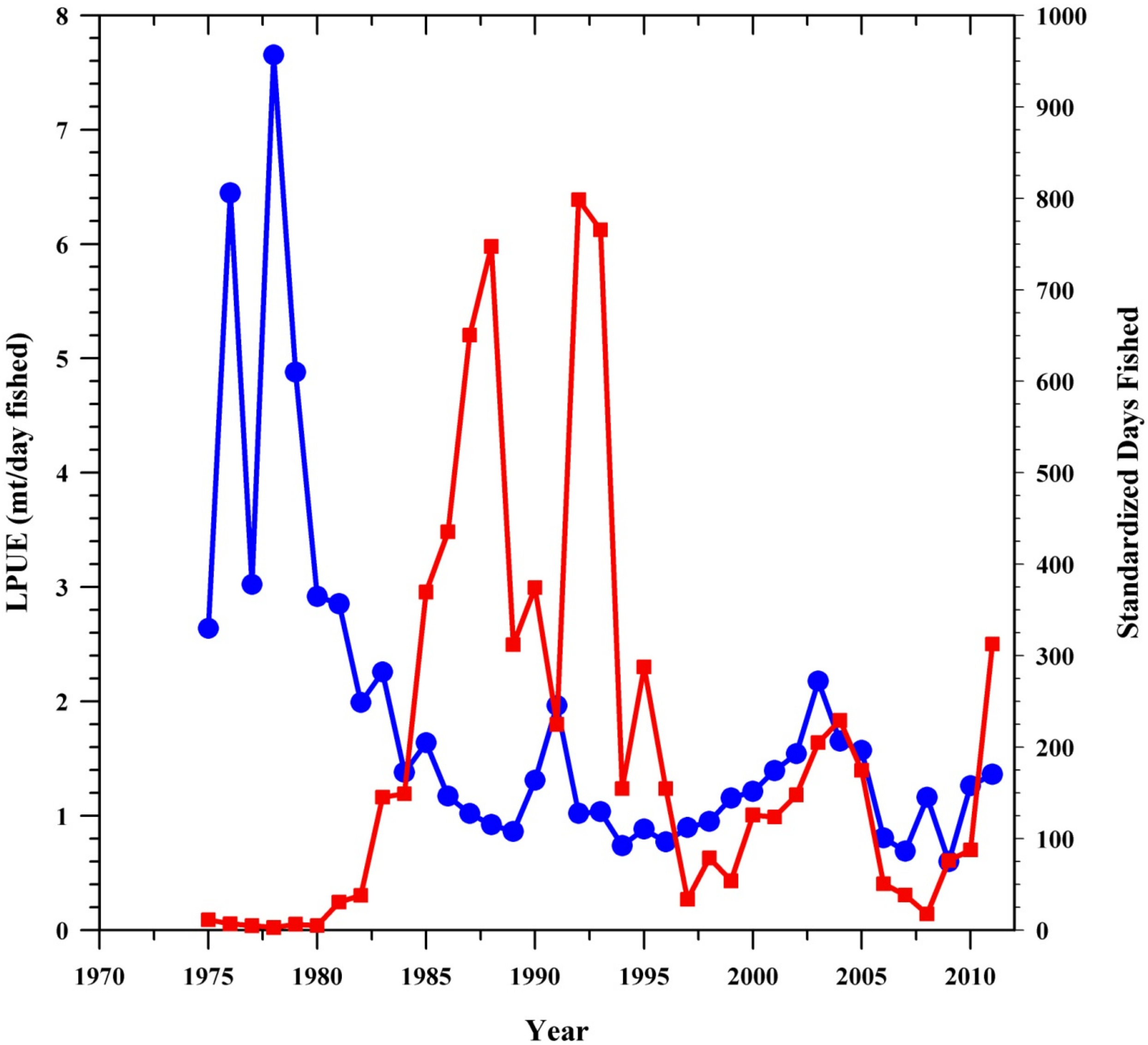


Figure B68. Standardized landings per day fished (LPUE, circles) and effort (solid line) of directed (>40%) white hake trips using a general linear model: year, quarter, area, and tonnage class.

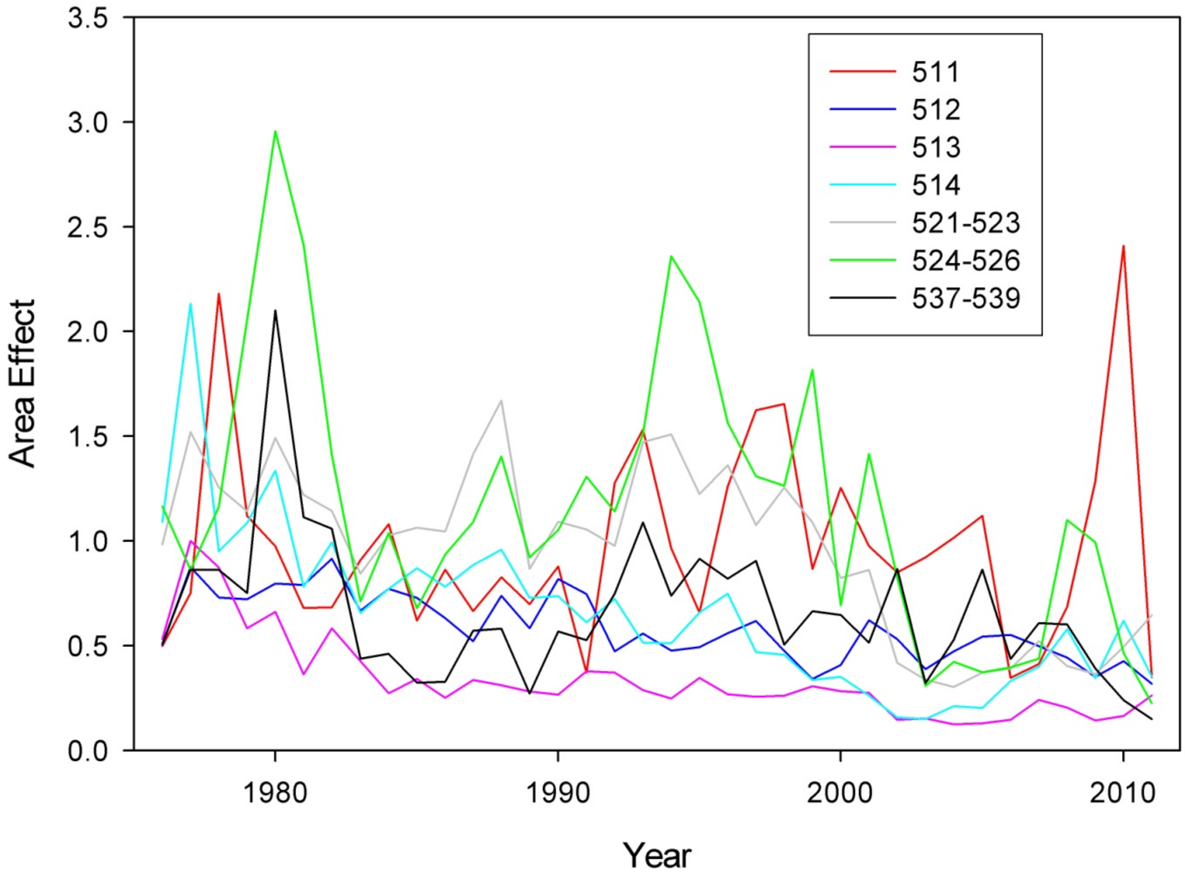


Figure B69. GLM results incorporating a year*area interaction term.

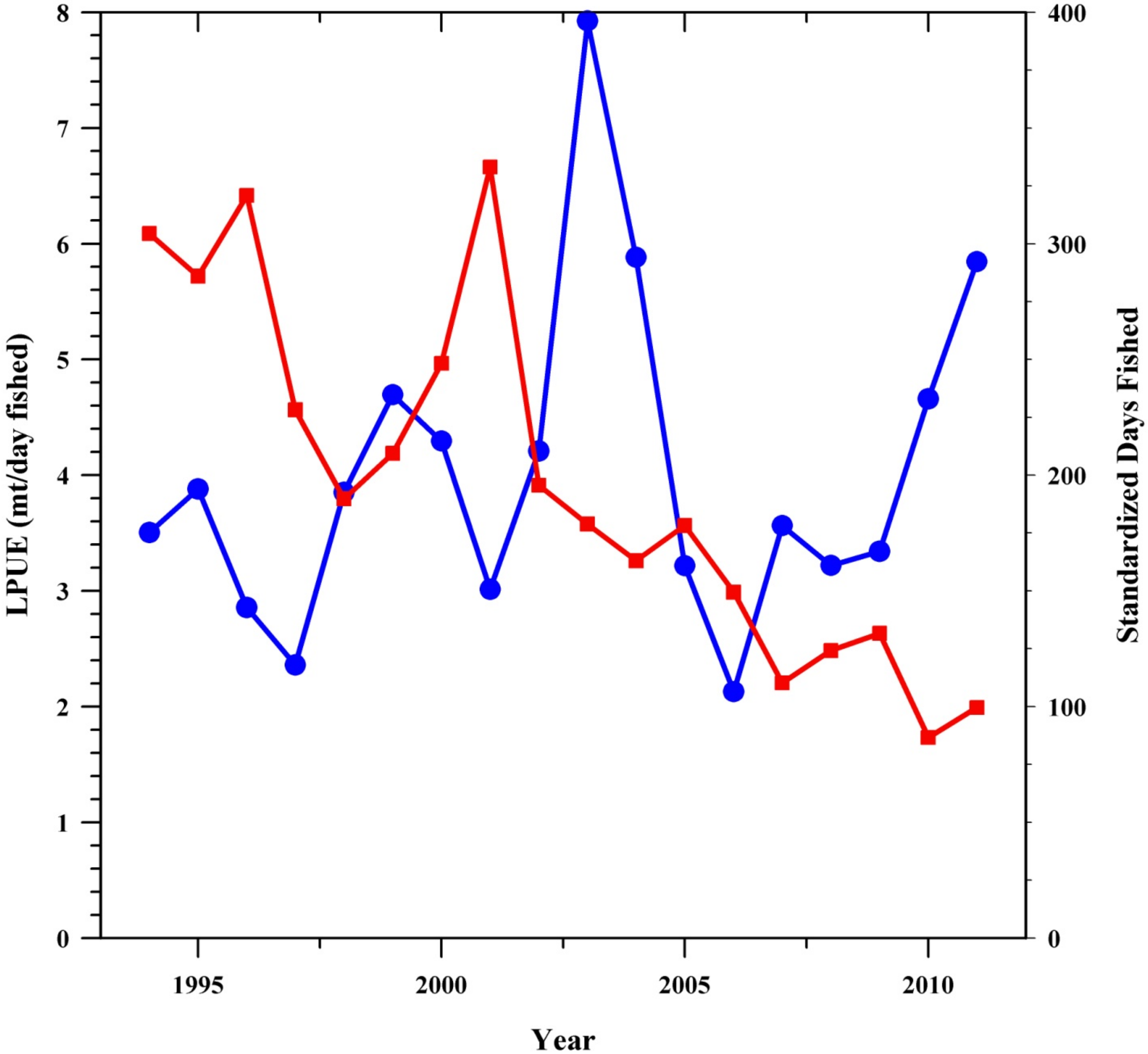


Figure B70. Standardized landings per day fished (LPUE, circles) and effort (days fished raised to total sink gill net landings, solid line) of all white hake trips using a general linear model: year, quarter, area, and tonnage class.

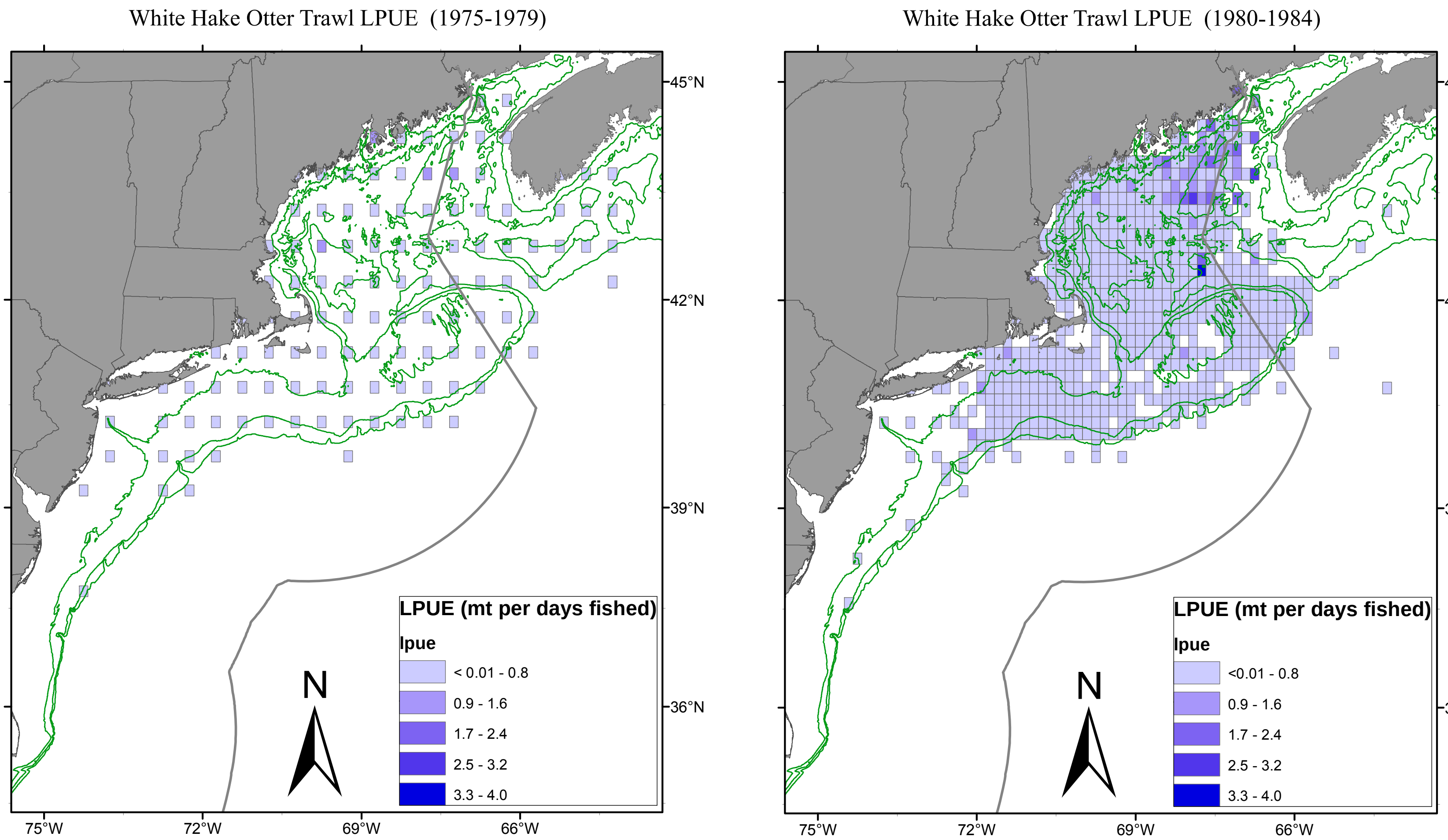
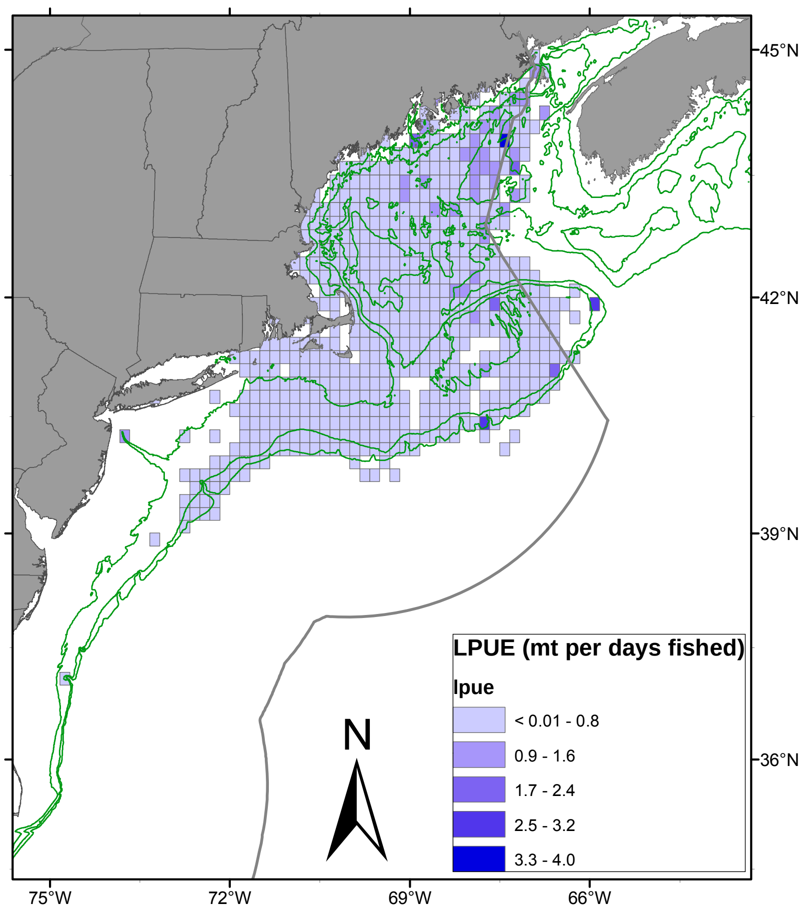


Figure B71. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the otter trawl fishery from 1975-1979 and 1980-1984.

White Hake Otter Trawl LPUE (1985-1989)



White Hake Otter Trawl LPUE (1990-1994)

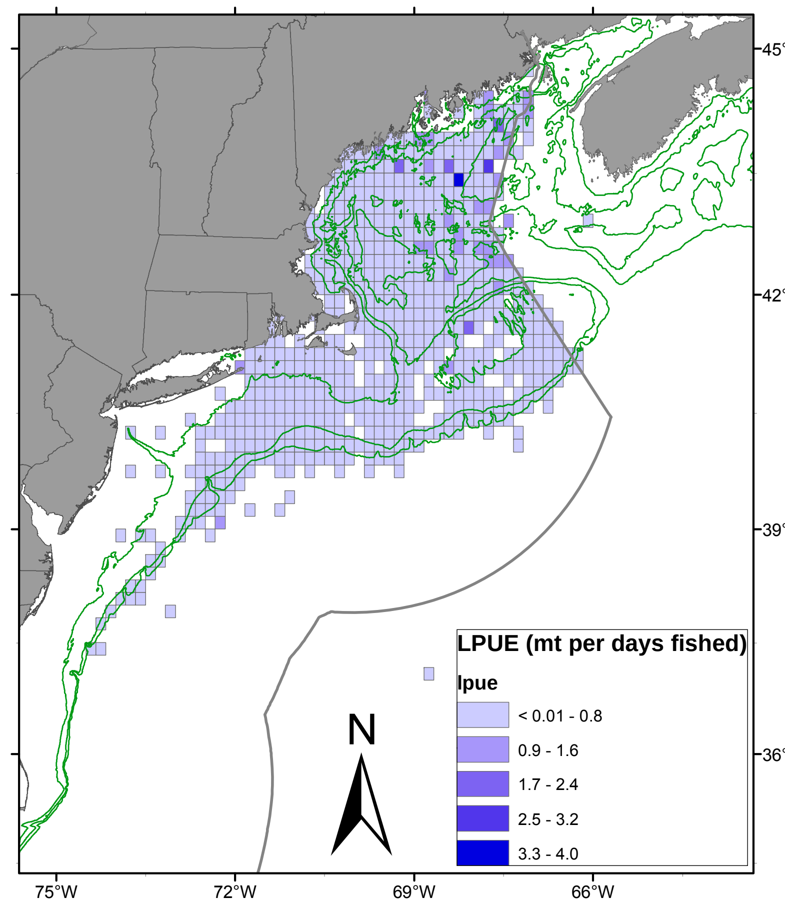
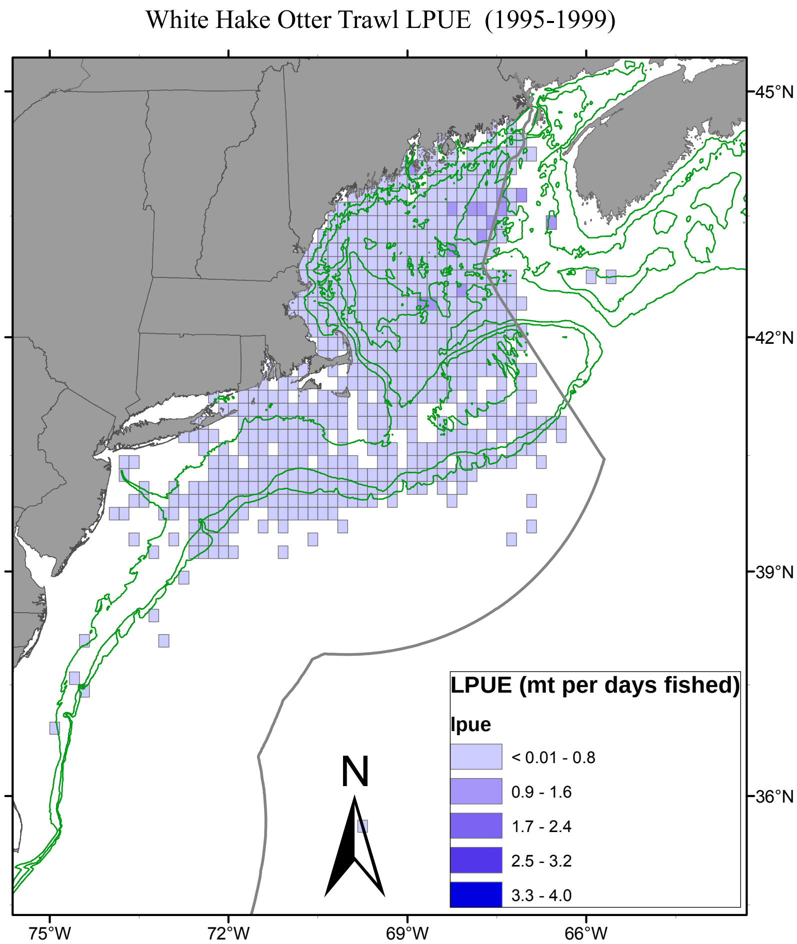


Figure B72. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the otter trawl fishery from 1985-1989 and 1990-1994.



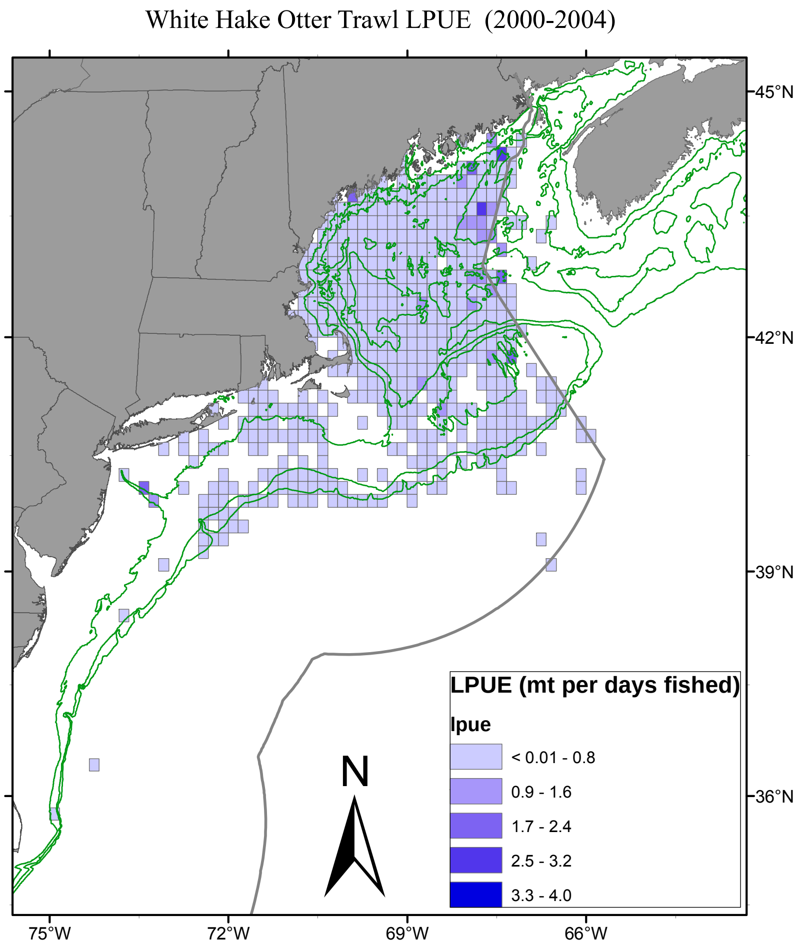


Figure B73. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the otter trawl fishery from 1995-1999 and 2000-2004.

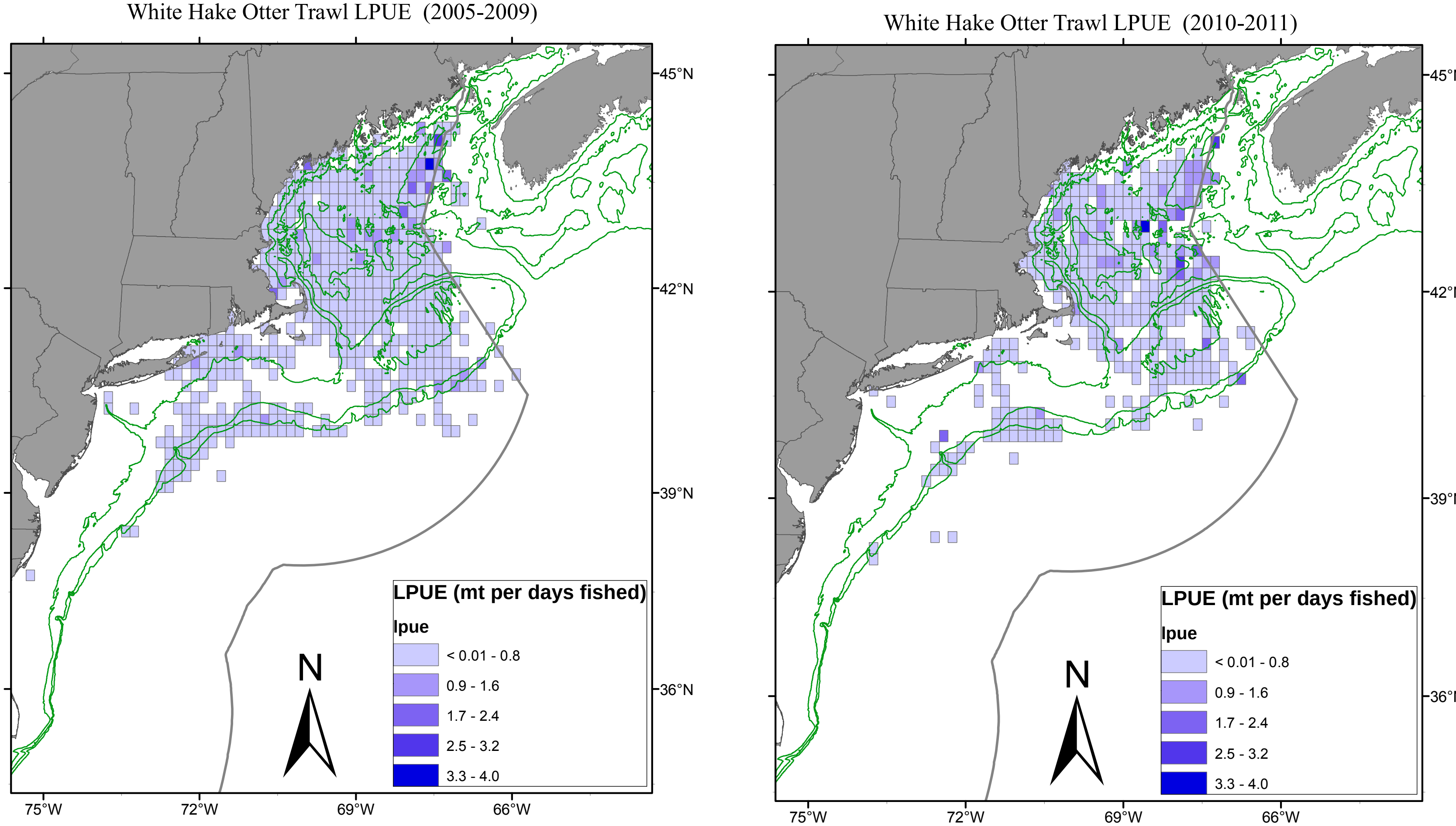


Figure B74. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the otter trawl fishery from 2005-2009 and 2010-2011.

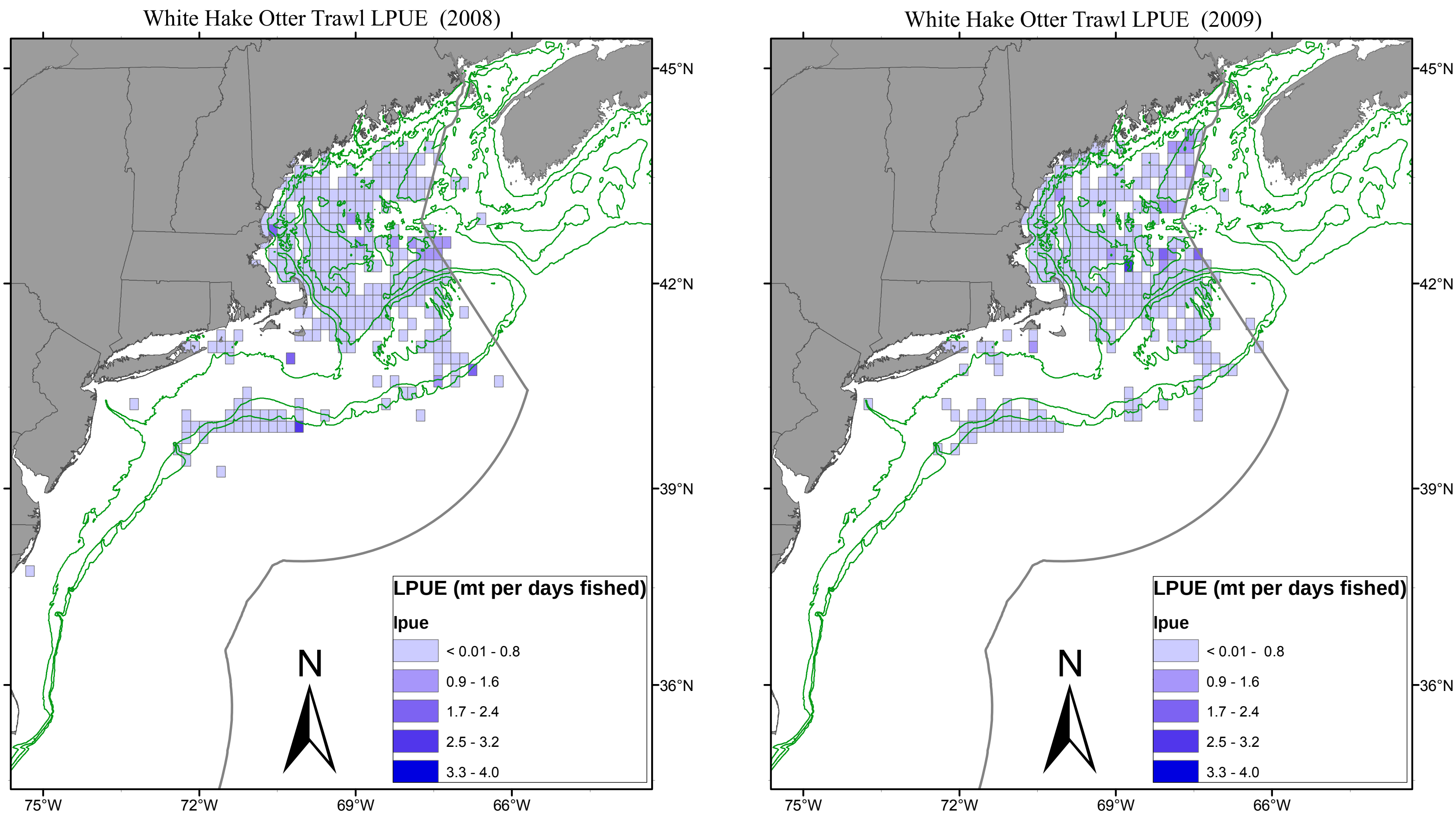
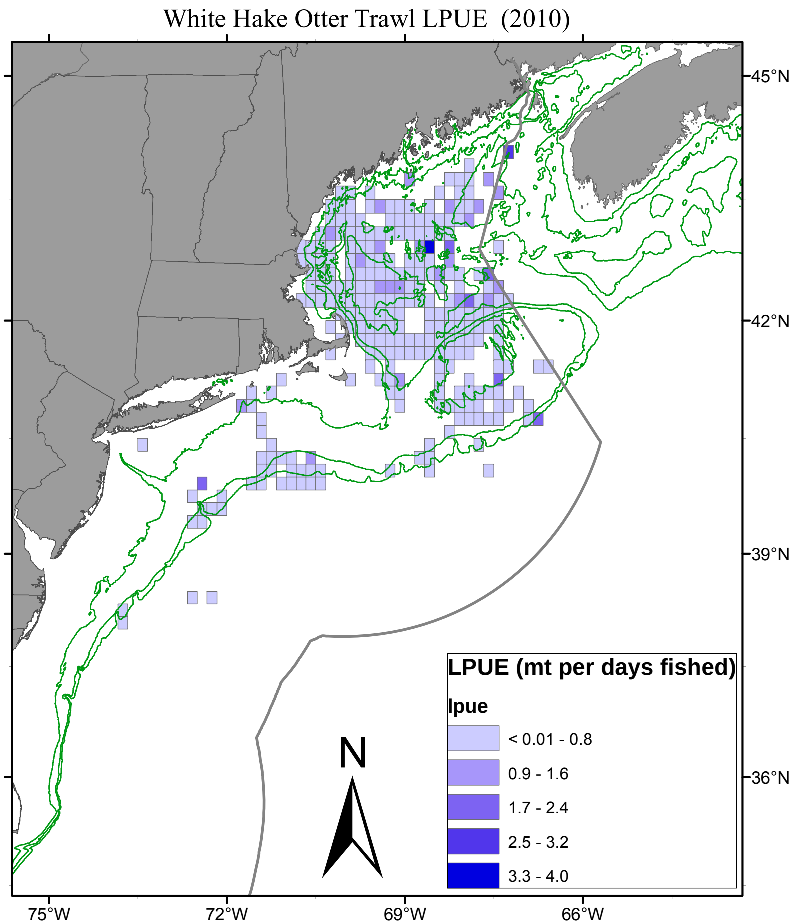


Figure B75a. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the otter trawl fishery from 2008-2011.



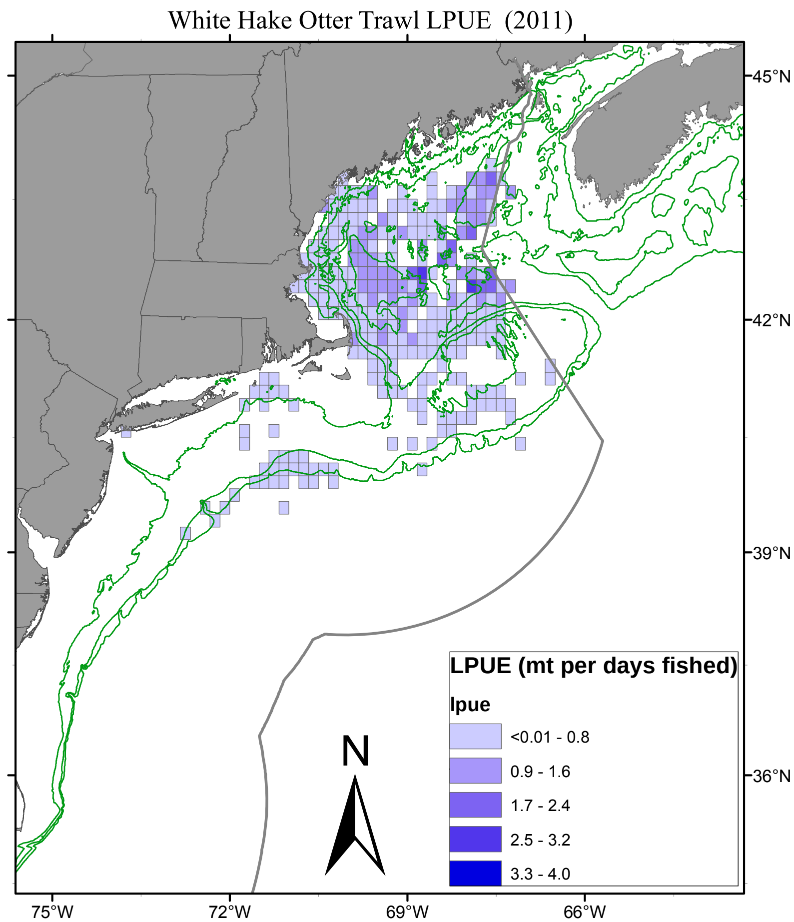


Figure B75b. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the otter trawl fishery from 2008-2011.

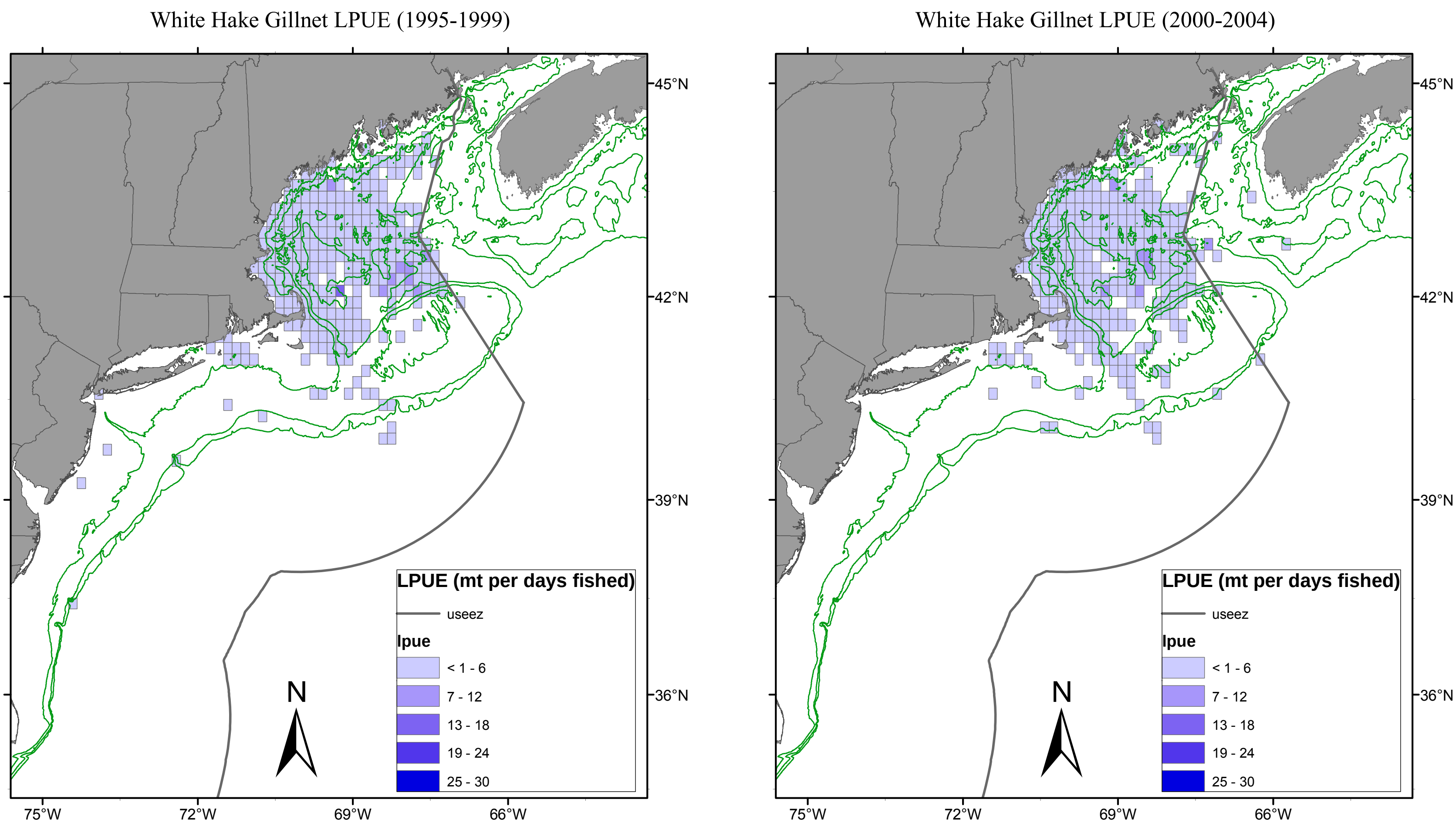


Figure B76. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the sink gill net fishery from 1995-1999 and 2000-2004.

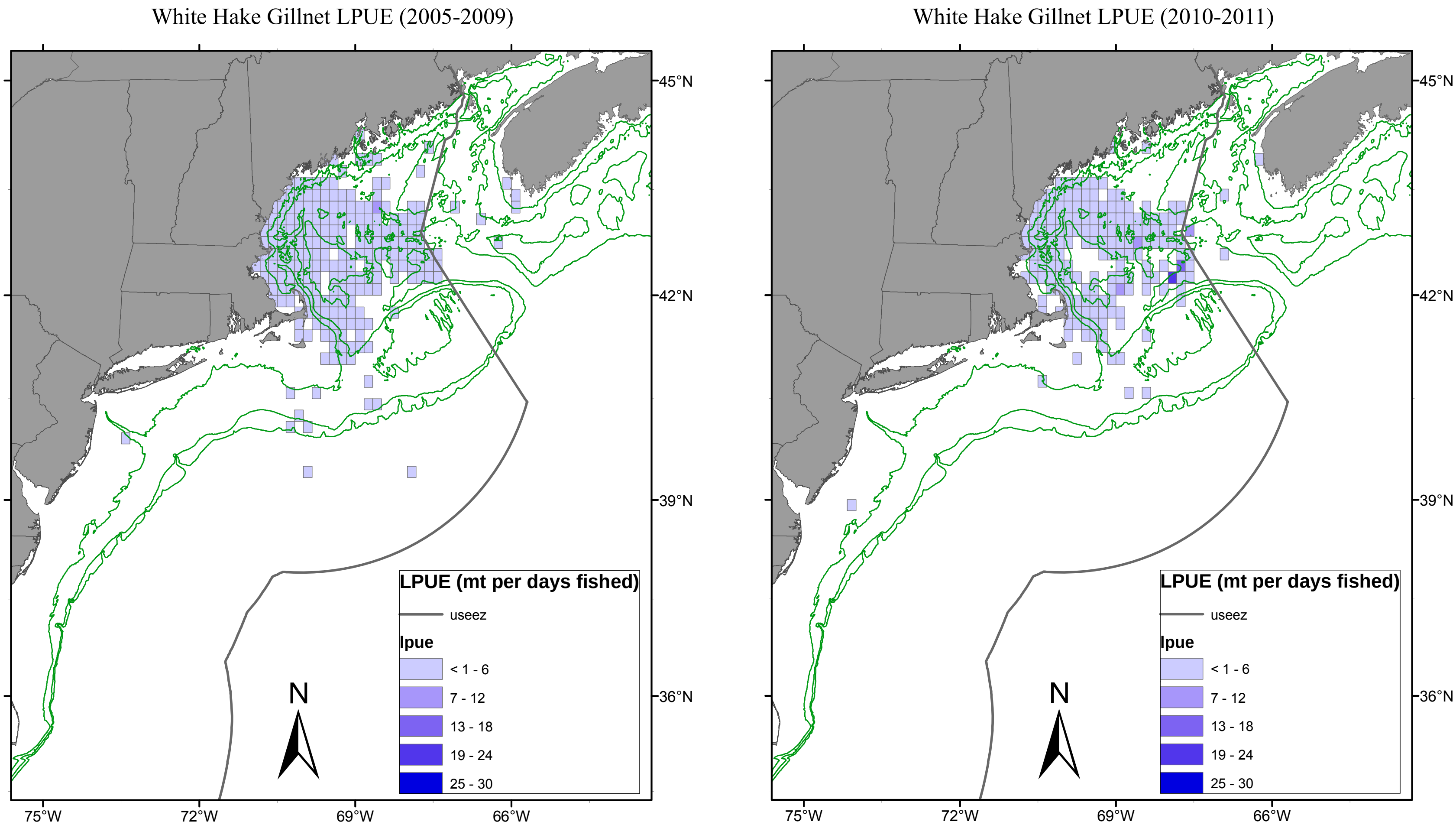


Figure B77. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the sink gill net fishery from 2005-2009 and 2010-2011.

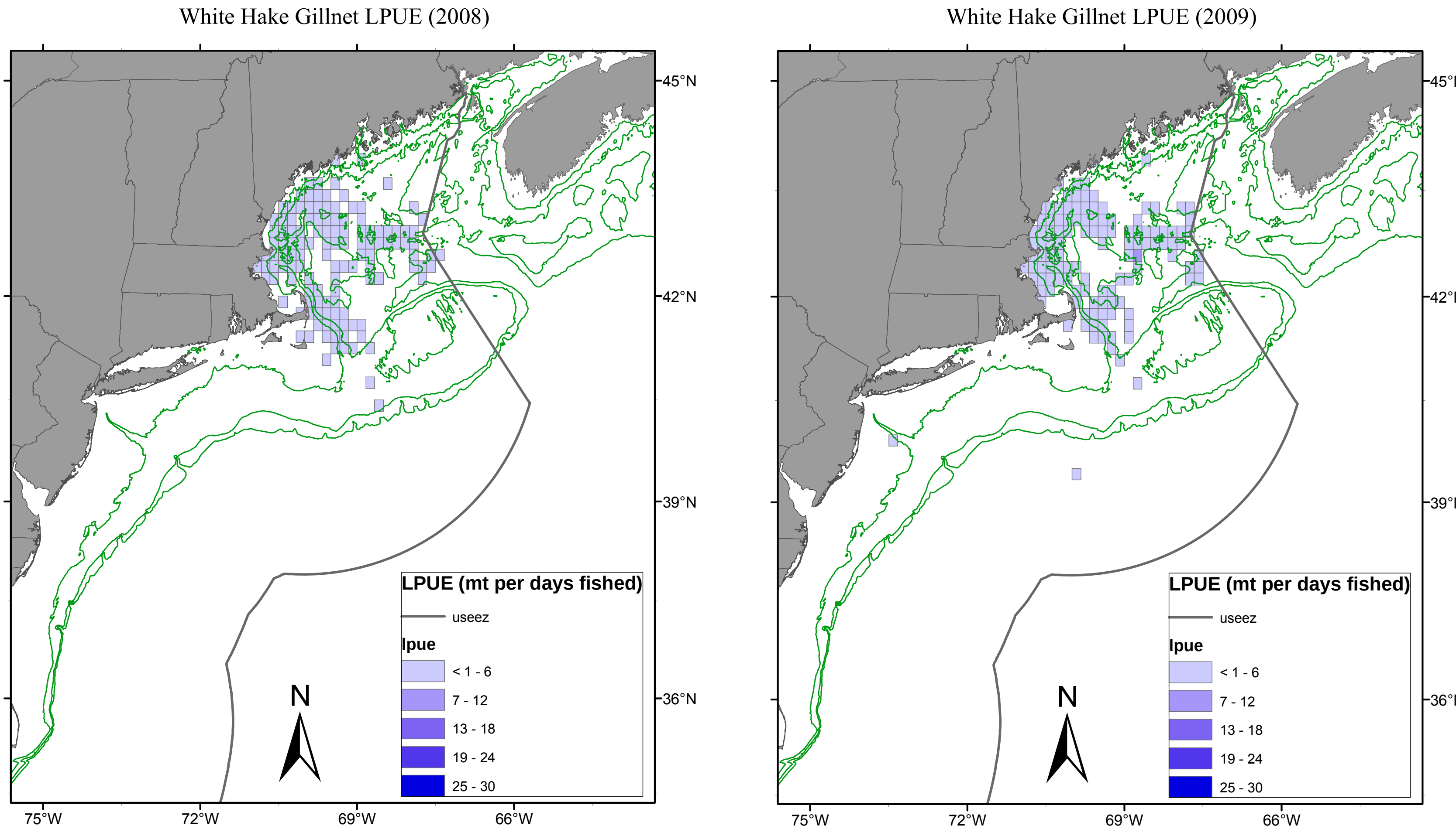


Figure B78a. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the sink gill net fishery from 2008-2011.

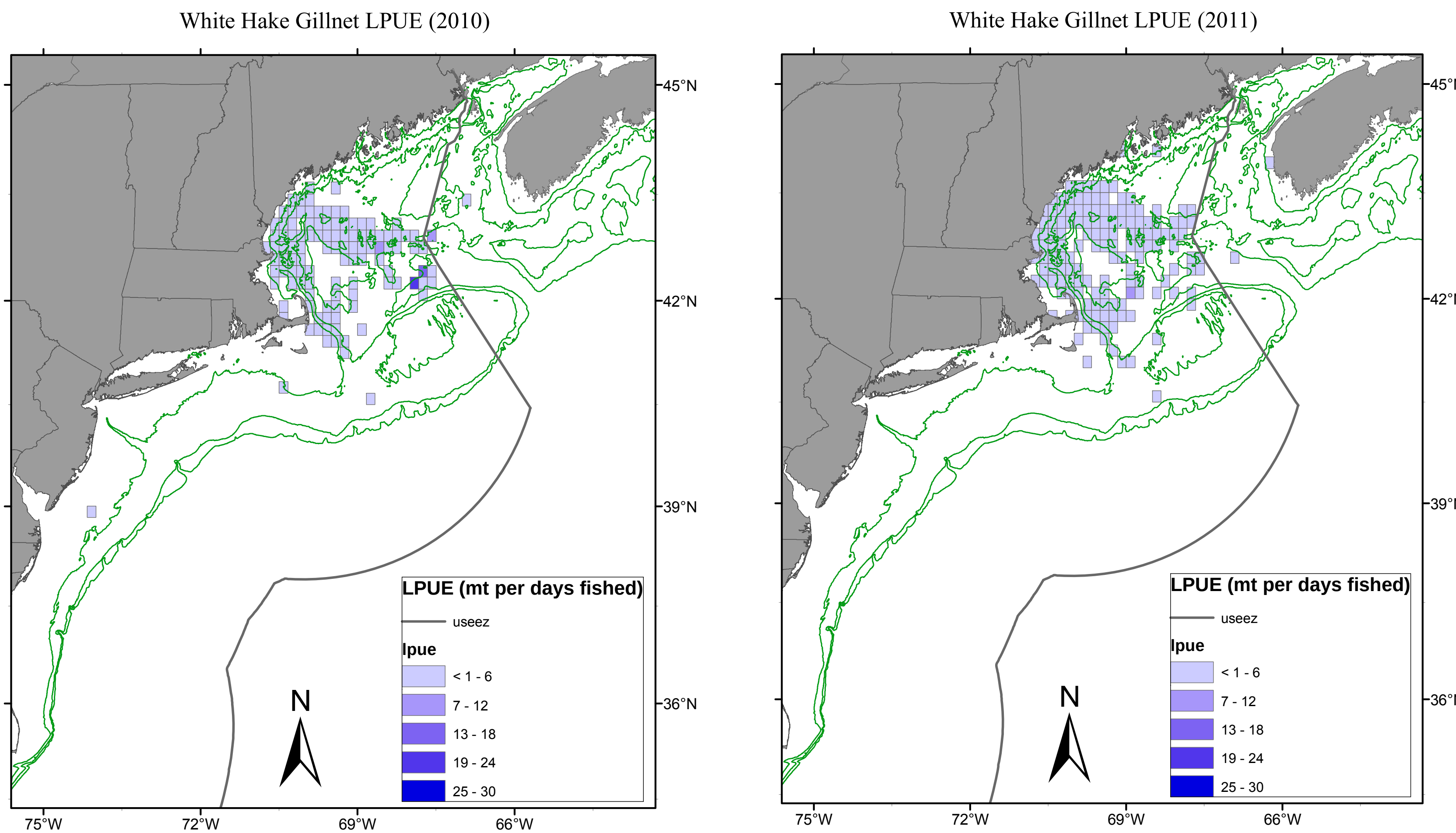


Figure B78b. Weighted LPUE (sum pounds landed in a ten-minute square/ sum of days fished in that ten-minute square) from the sink gill net fishery from 2008-2011.

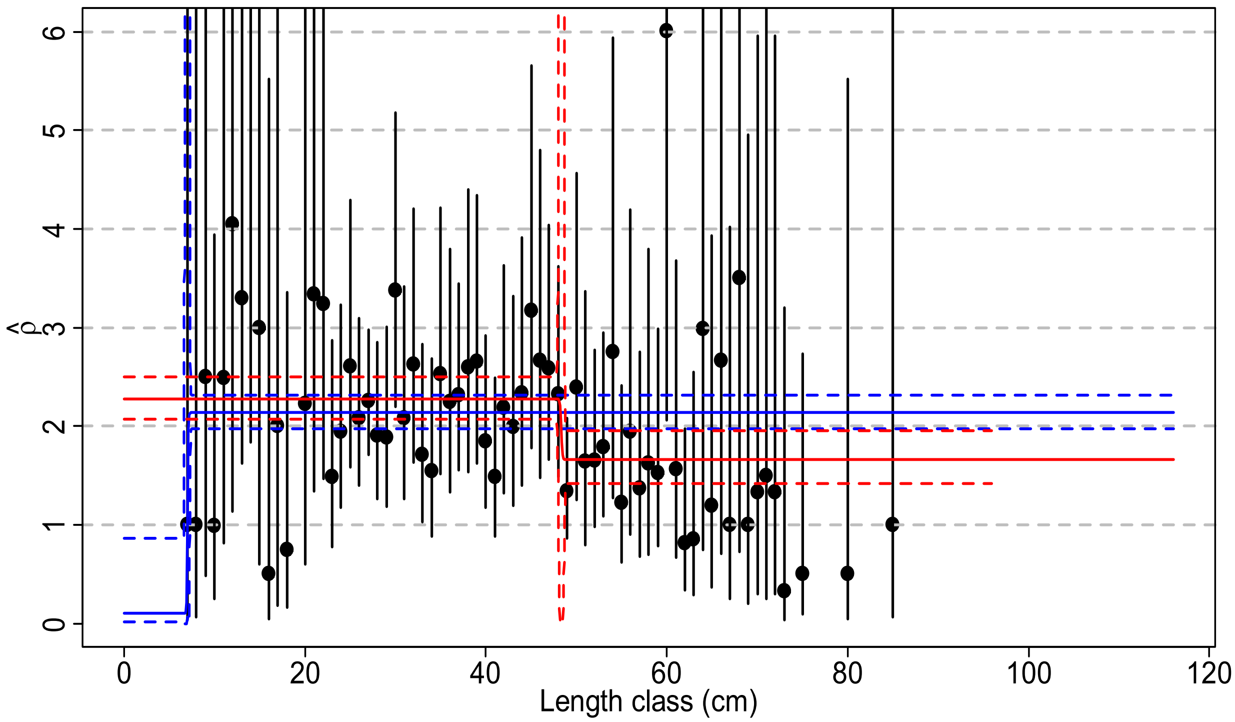


Figure B79. Beta-binomial based estimates of calibration factors and corresponding 95% confidence intervals by length class (1 cm bins) for **white hake**. The black points and vertical bars represent results where different calibration factors are estimated for each length class. The blue lines represent results from logistic model where the slope is estimated to be positive whereas the red lines represent results from a logistic model where the slope is forced to be negative.

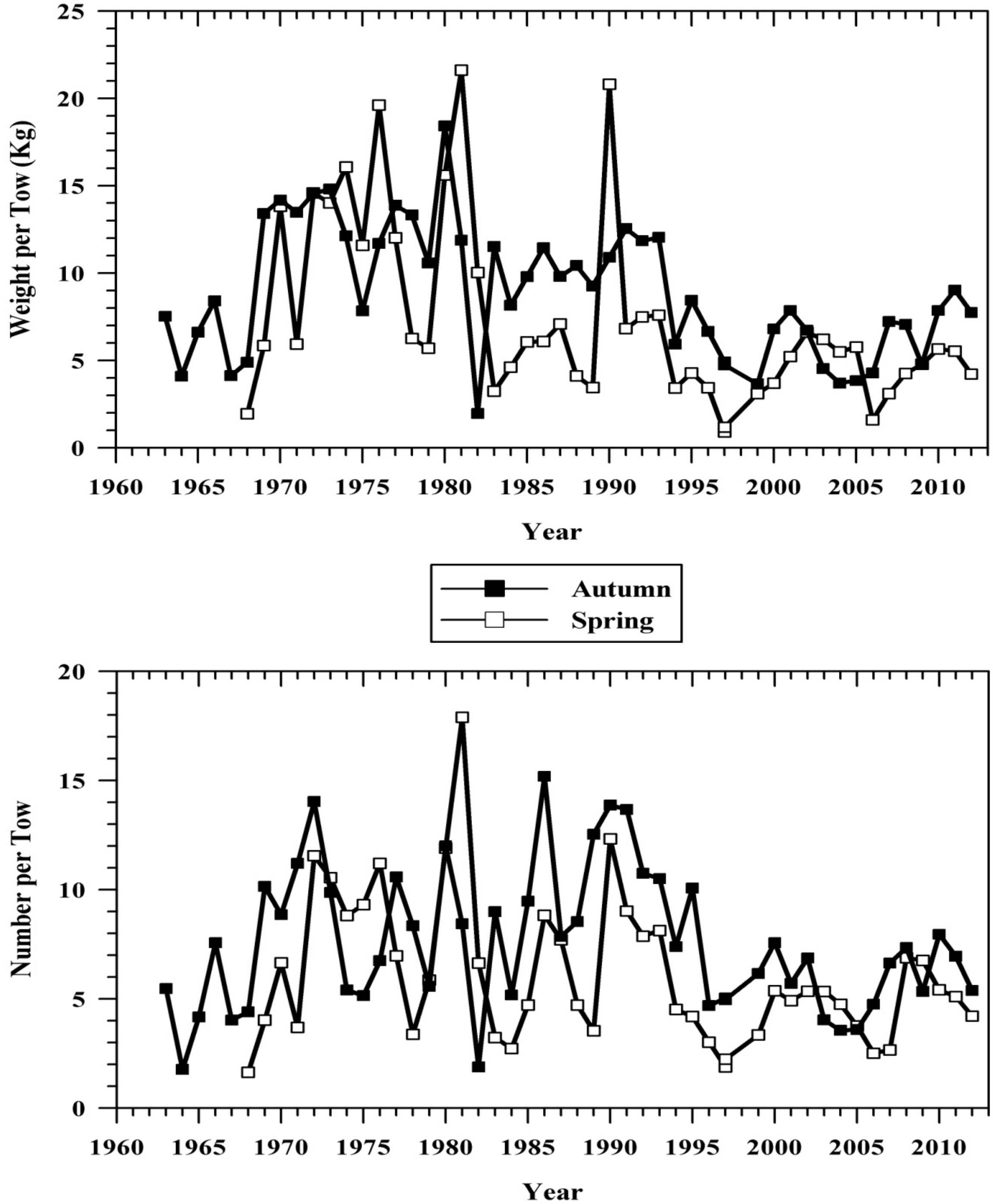


Figure B80. White hake indices of biomass (top panel) and abundance (bottom panel) from the NEFSC bottom trawl spring (solid line) and autumn (dashed line) surveys in the Gulf of Maine to Northern Georges Bank region (offshore strata 21-30, 36-40), 1963-2012.

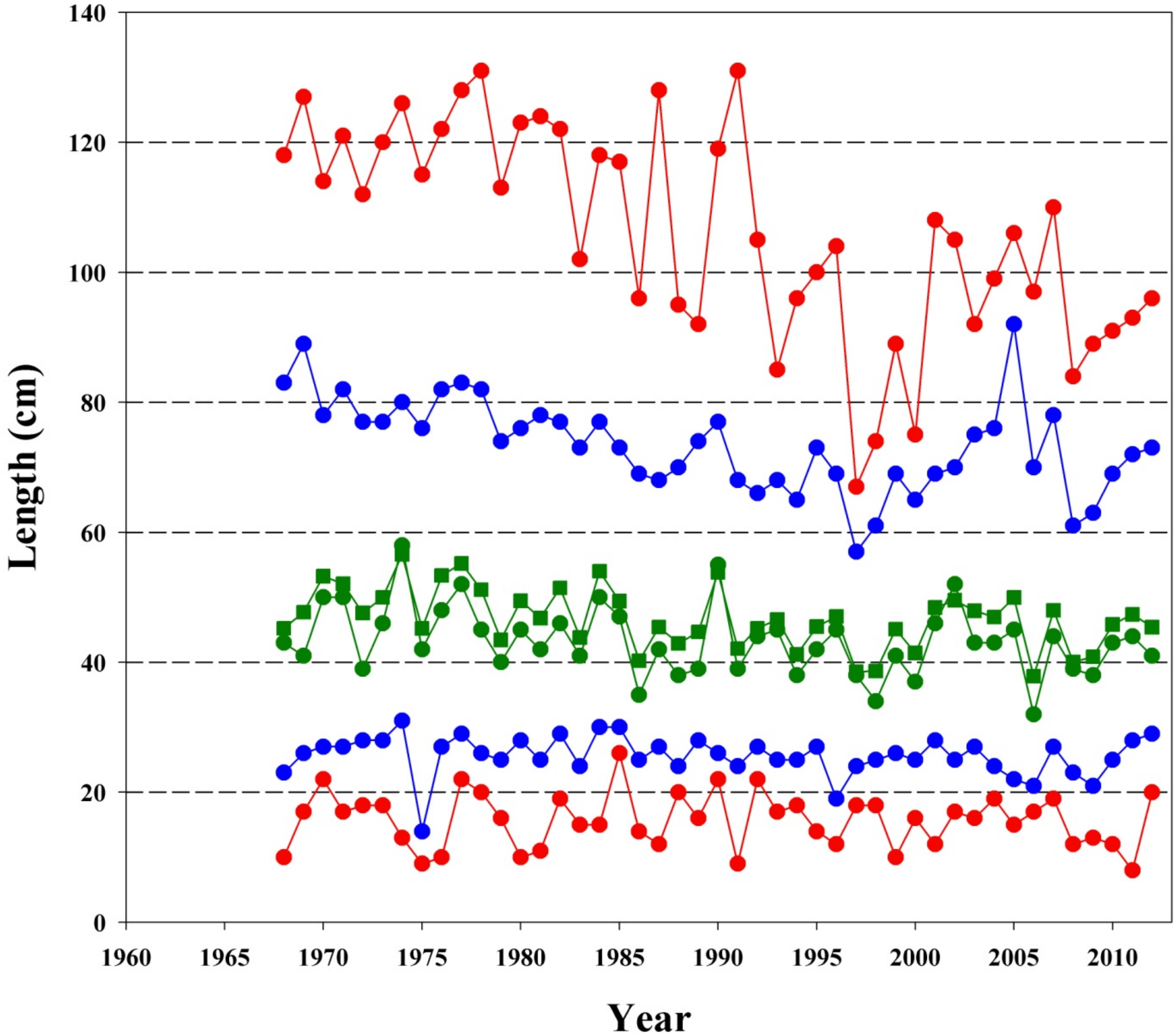


Figure B81. Minimum and maximum (red circles), 5th and 95th percentiles (blue circles), mean (green squares) and 50th percentile (green circles) of white hake length from the NEFSC spring bottom trawl surveys.

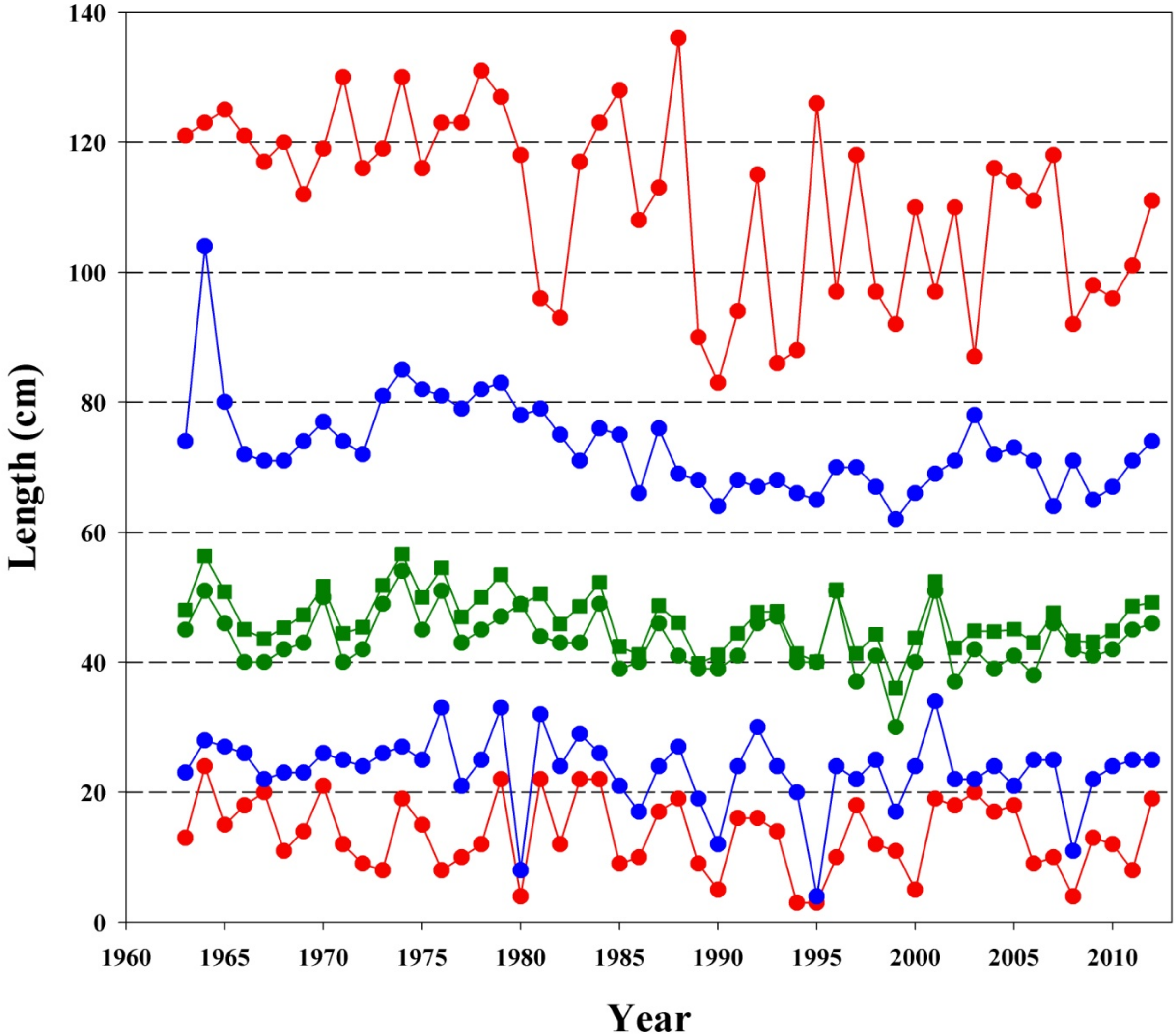


Figure B82. Minimum and maximum (red circles), 5th and 95th percentiles (blue circles), mean (green squares) and 50th percentile (green circles) of white hake length from the NEFSC autumn bottom trawl surveys.

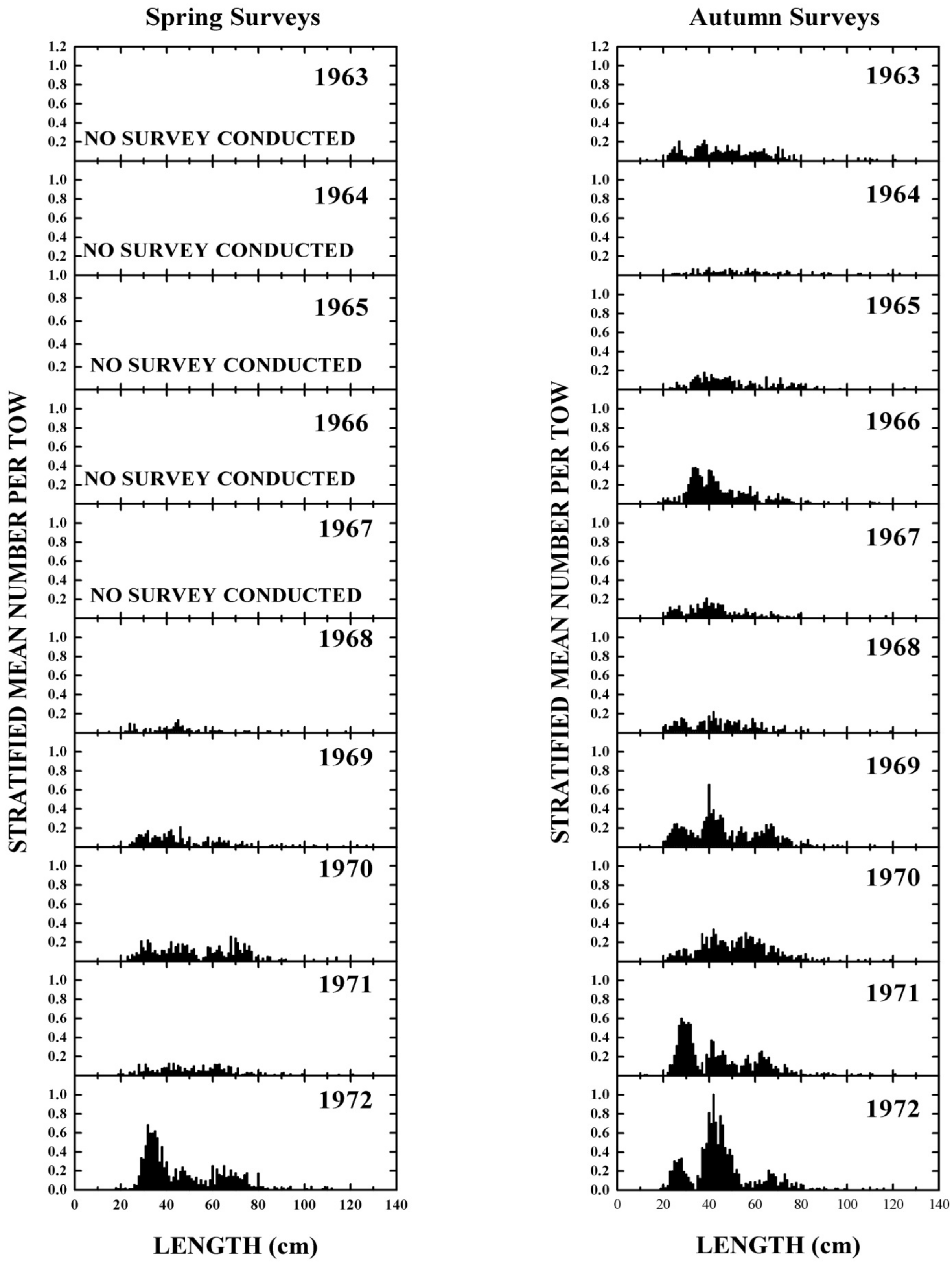


Figure B83a. Length composition of white hake from the NEFSC spring and autumn surveys from 1963-1972.

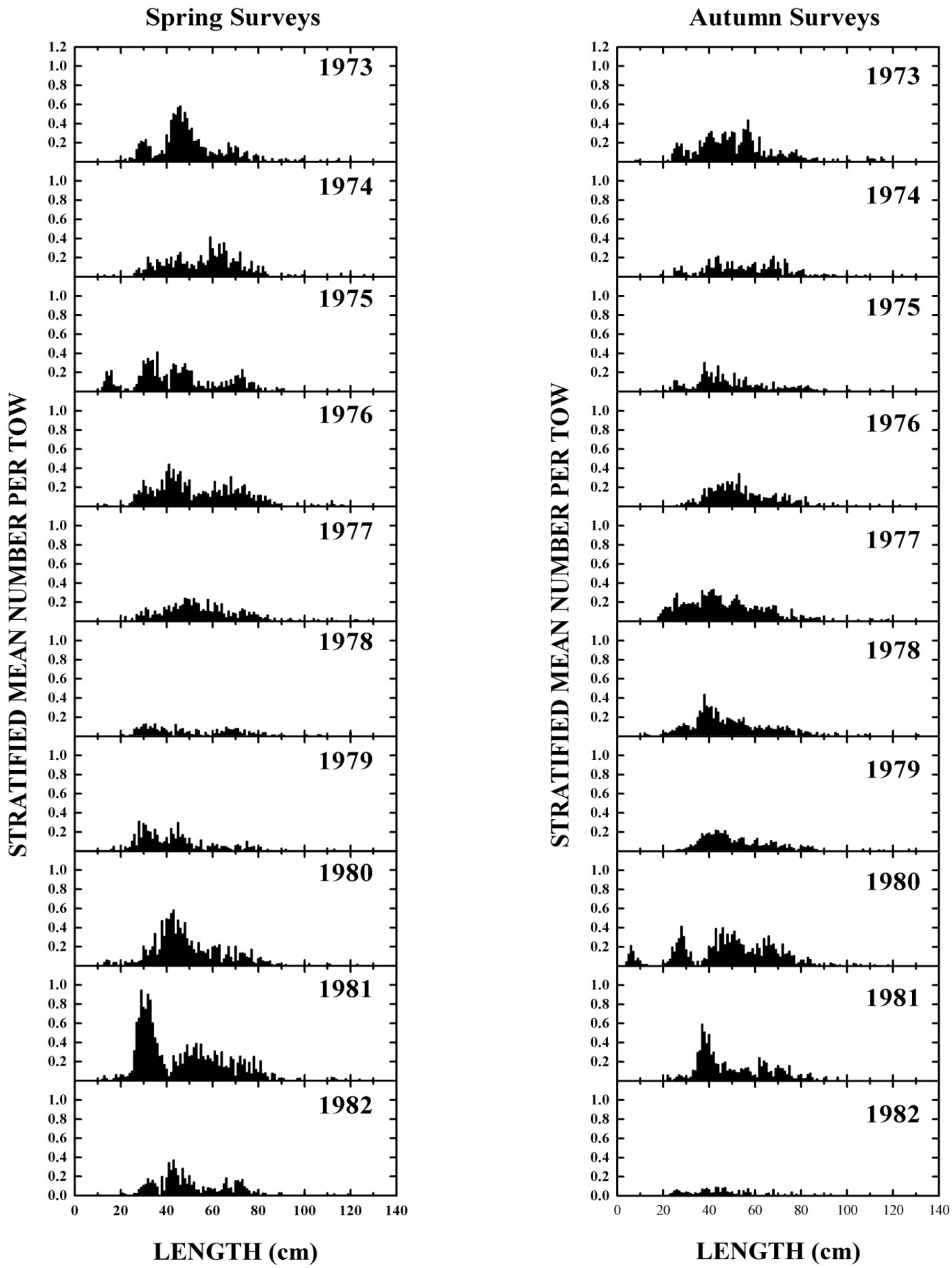


Figure B83b. Length composition of white hake from the NEFSC spring and autumn surveys from 1973-1982.

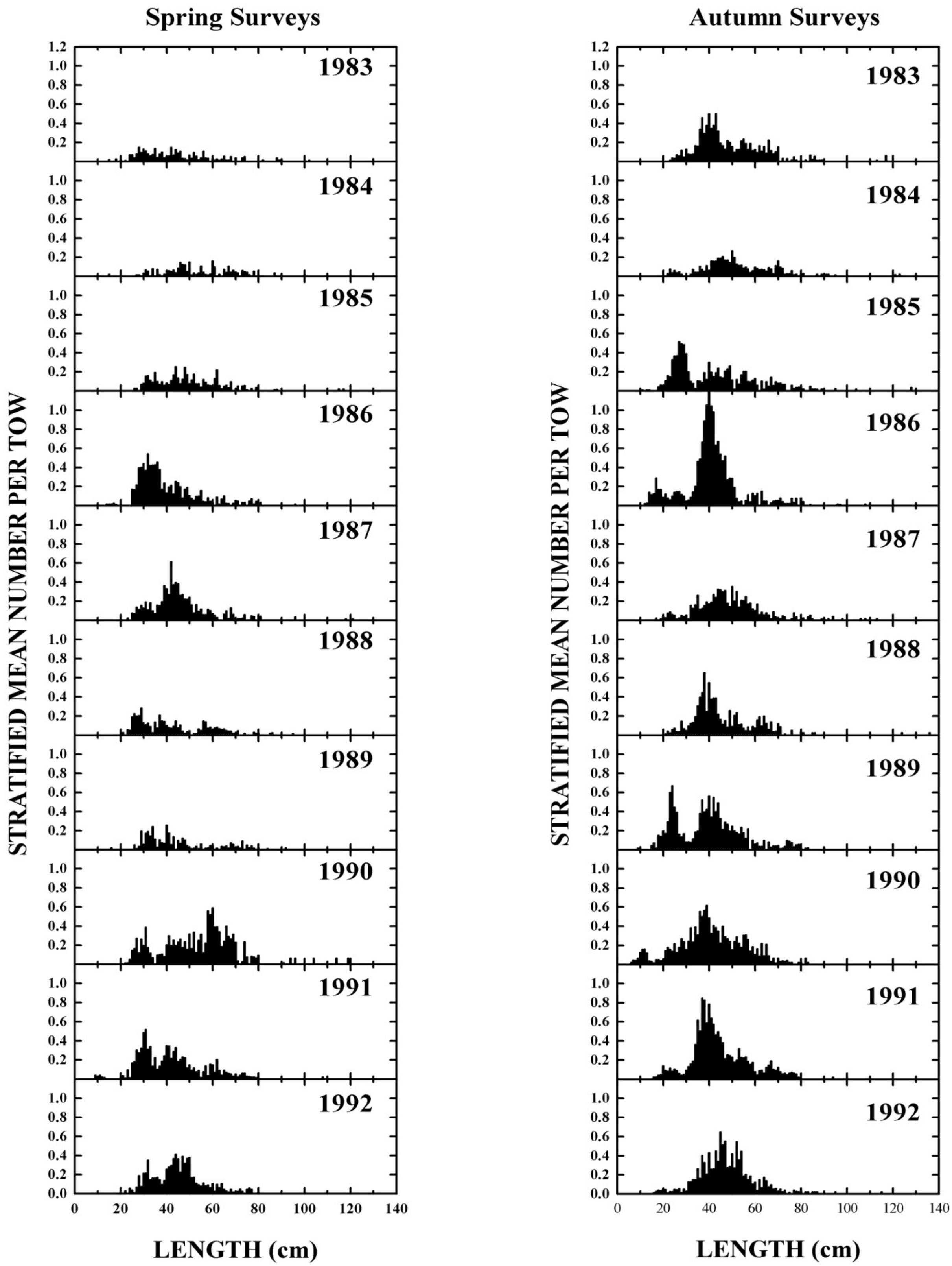


Figure B83c. Length composition of white hake from the NEFSC spring and autumn surveys from 1983-1992.

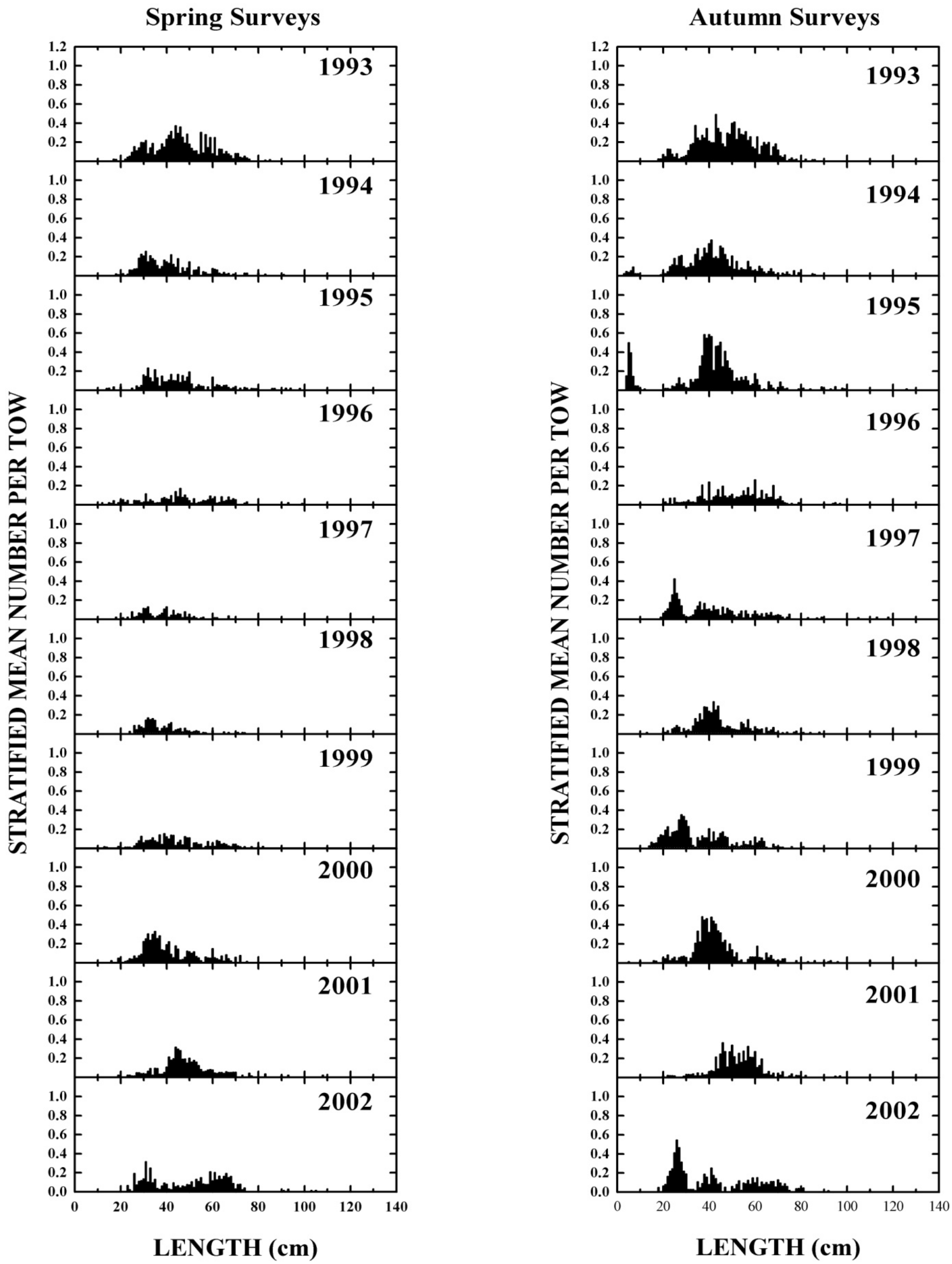


Figure B83d. Length composition of white hake from the NEFSC spring and autumn surveys from 1993-2002.

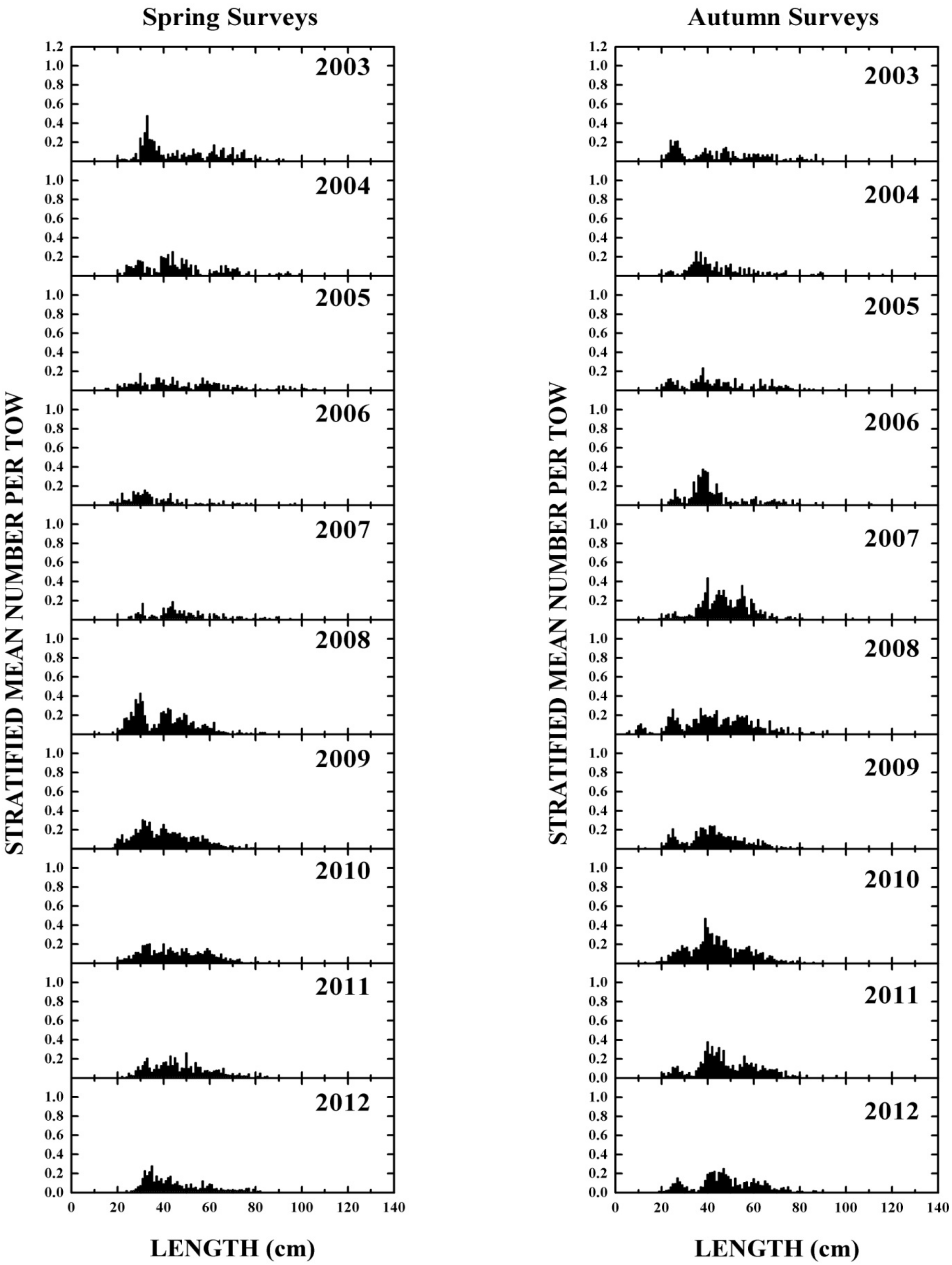
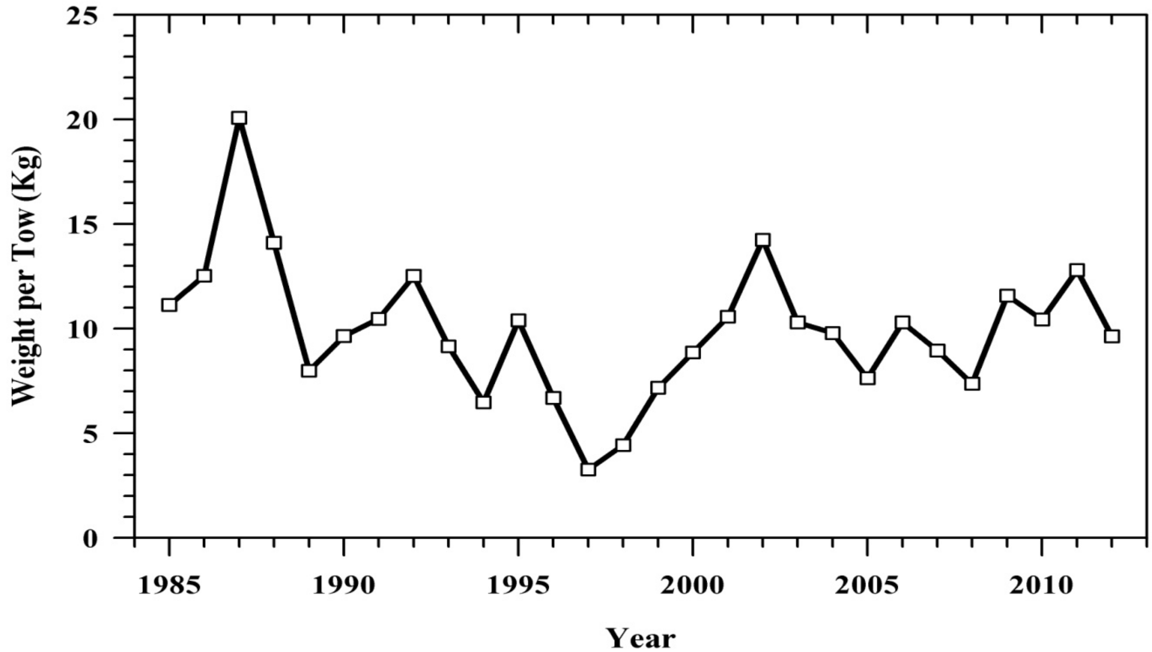


Figure B83e. Length composition of white hake from the NEFSC spring and autumn surveys from 2003-2012.



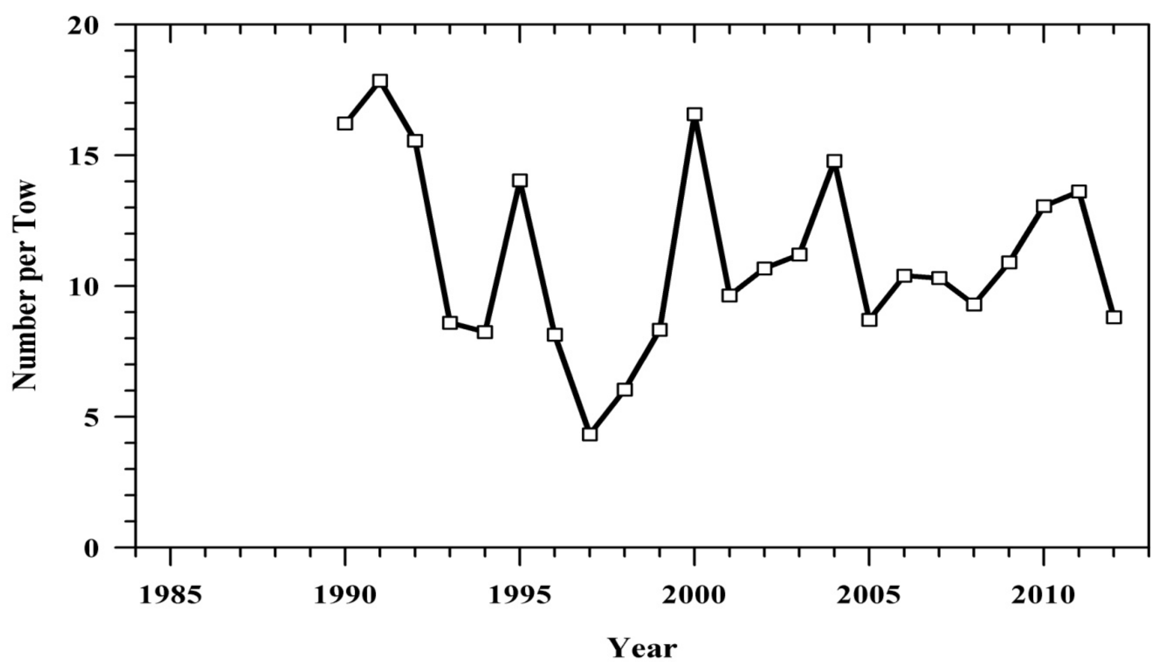


Figure B84. White hake indices of biomass (top panel) and abundance (bottom panel) from the ASMFC shrimp trawl surveys in the Gulf of Maine (shrimp strata 1,3, 5-8), 1985-2012.

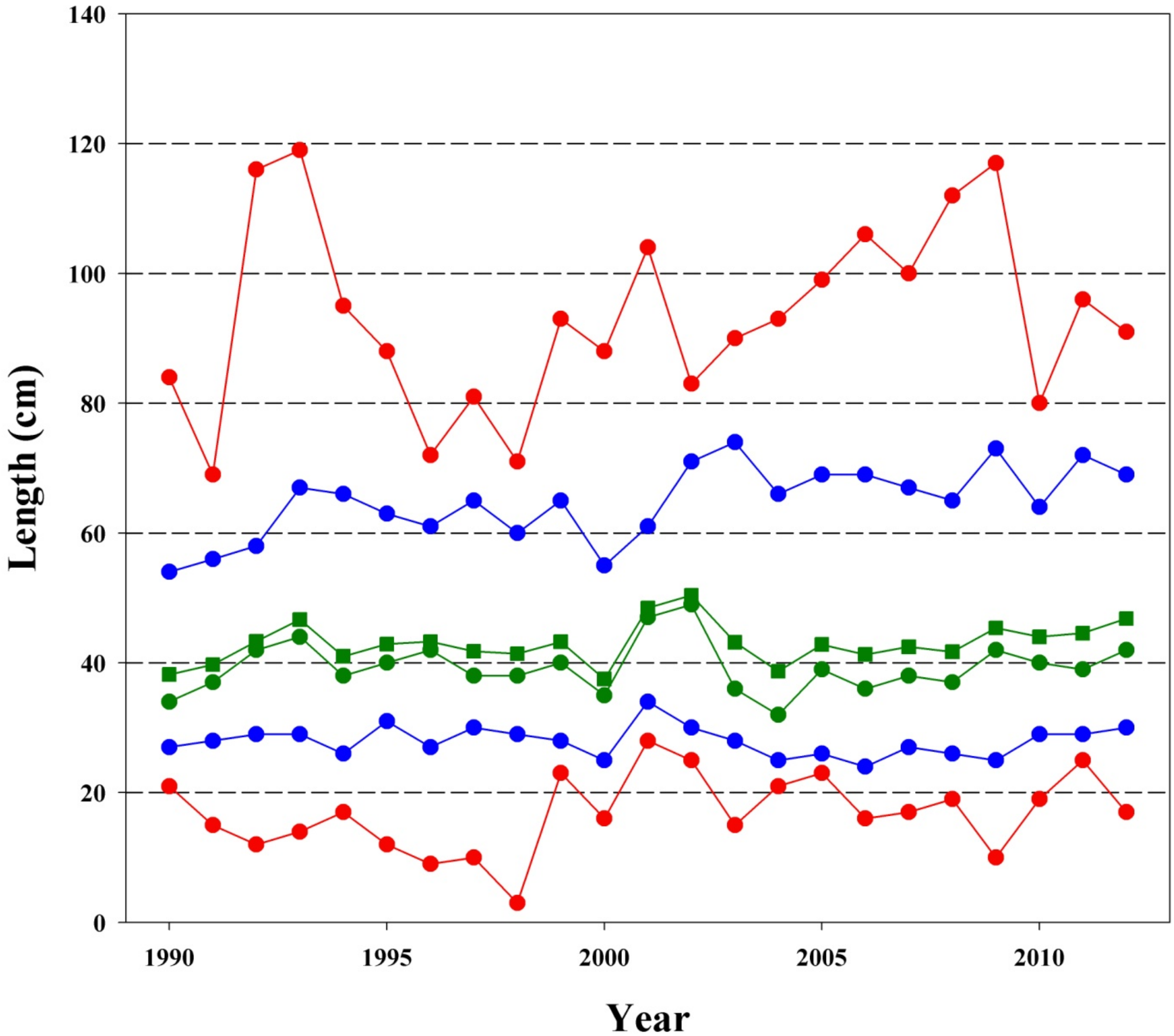


Figure B85. Minimum and maximum (red circles), 5th and 95th percentiles (blue circles), mean (green squares) and 50th percentile (green circles) of white hake length from the ASMFC shrimp surveys.

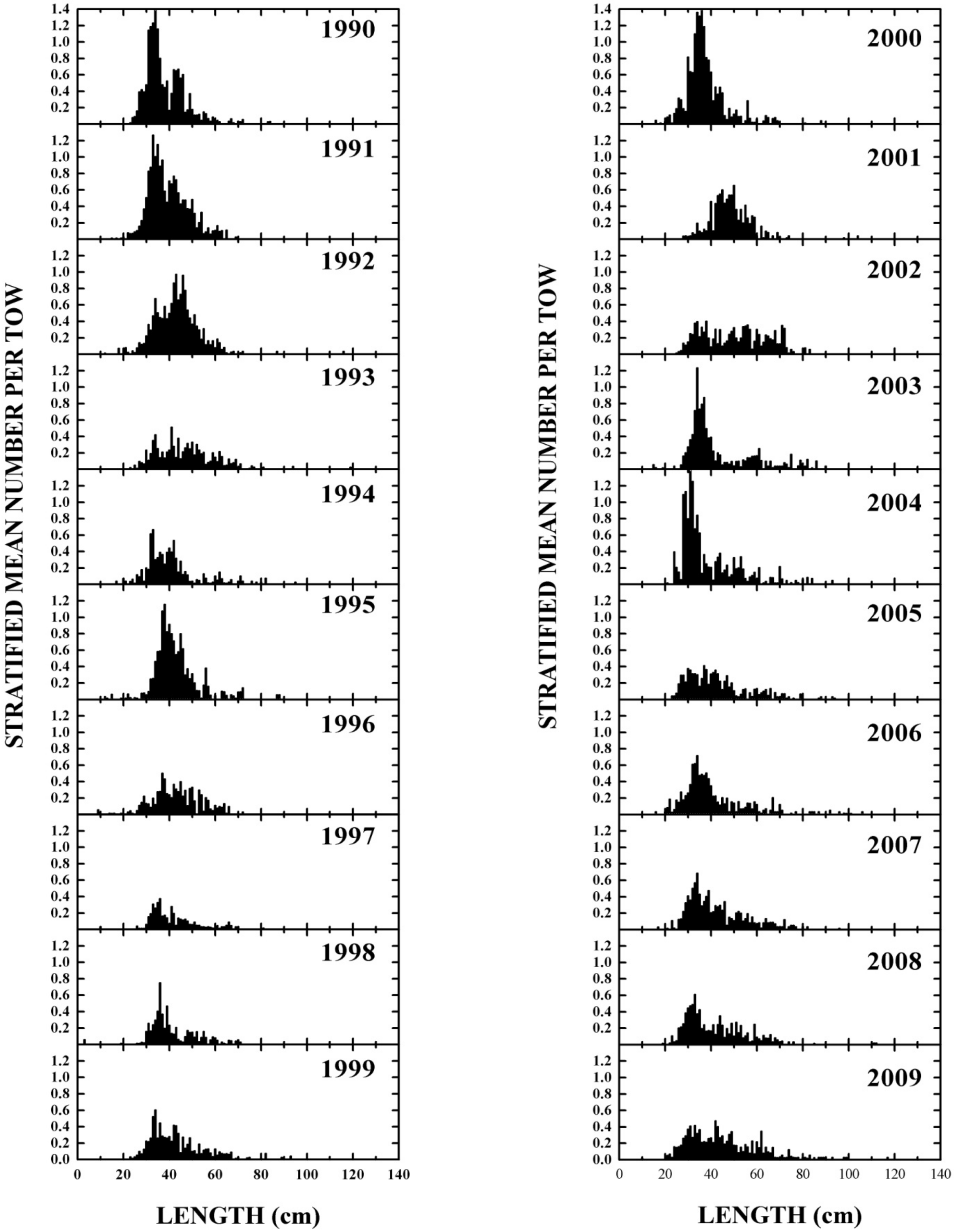


Figure B86a. Length composition of white hake from the ASMFC shrimp survey from 1990-2009.

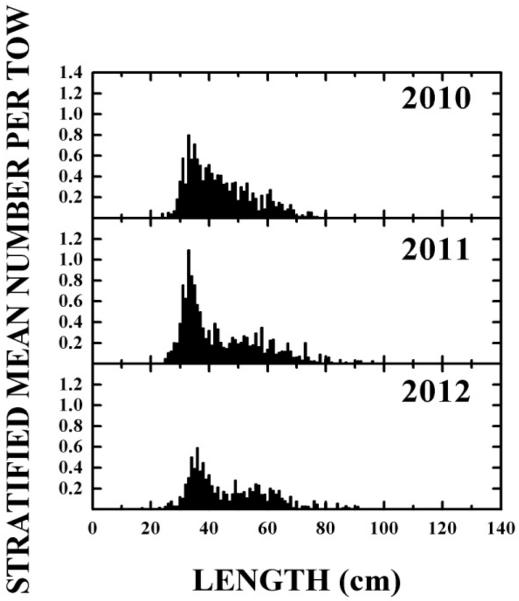

STRATIFIED MEAN NUMBER PER TOW
LENGTH (cm)
2010
2011
2012
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
20
40
60
80
100
120
140

Figure B86b. Length composition of white hake from the ASMFC shrimp survey from 2010-2012.

Region	Stratum	Area(nm²)
1. Buzzards Bay Vineyard Sd & coastal water south of Marthas Vineyard	11	102
	12	160
	13	88
	14	16
2. Nantucket Sound	15	190
	16	212
3. East of Cape Cod Race Point to Muskeget Island	17	85
	18	88
	19	39
	20	24
	21	40
4. Cape Cod Bay	25	47
	26	87
	27	94
	28	93
	29	103
	30	32
5. Massachusetts Bay north to N.H. border	31	41
	32	49
	33	78
	34	38
	35	174
	36	33

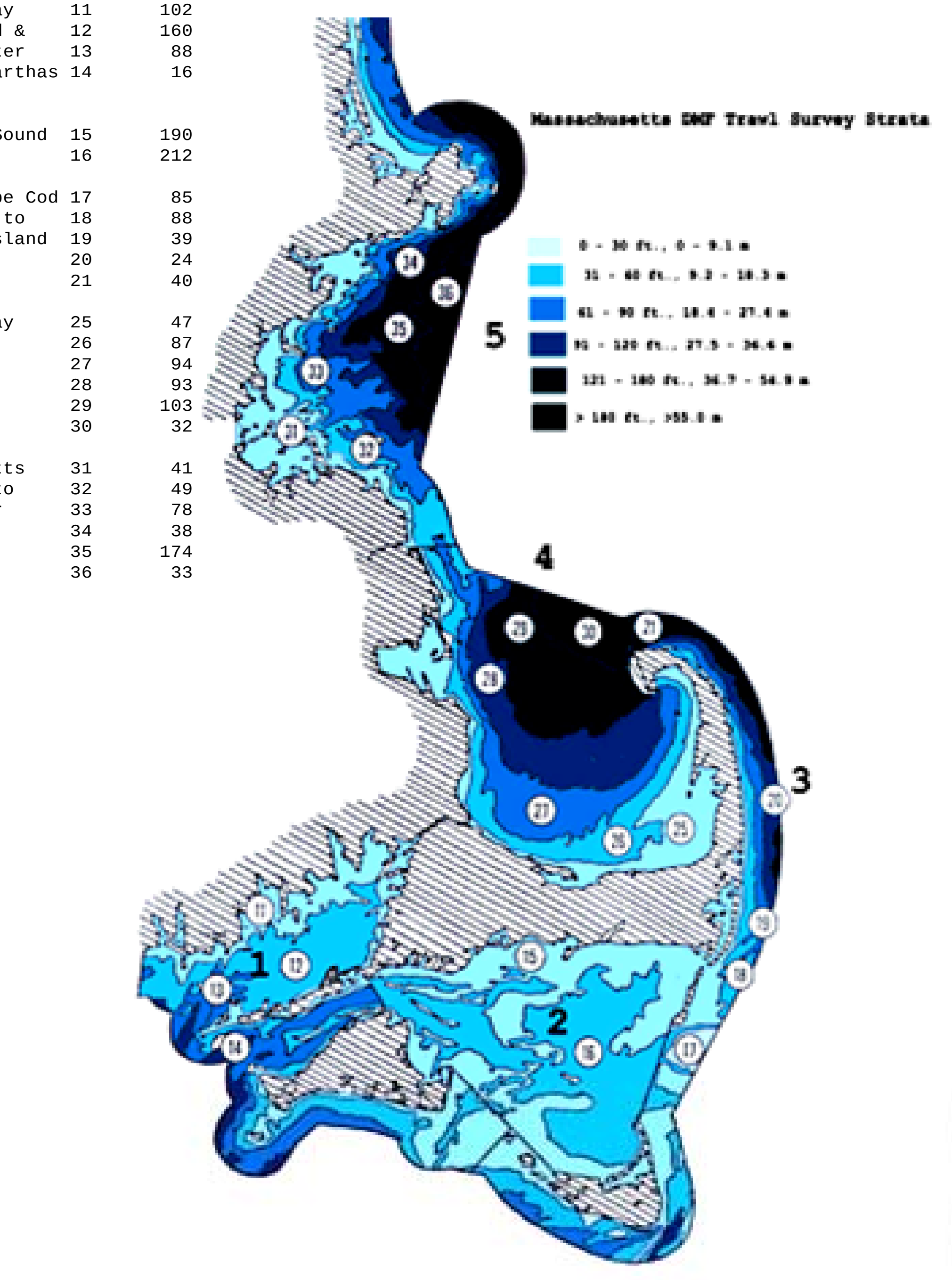
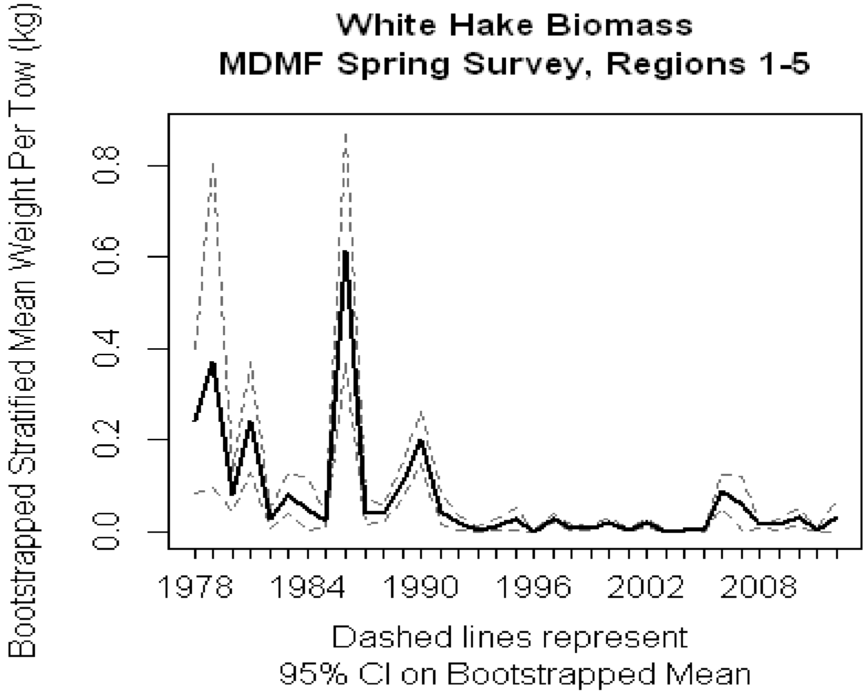


Figure B87. Strata used in the Massachusetts survey.



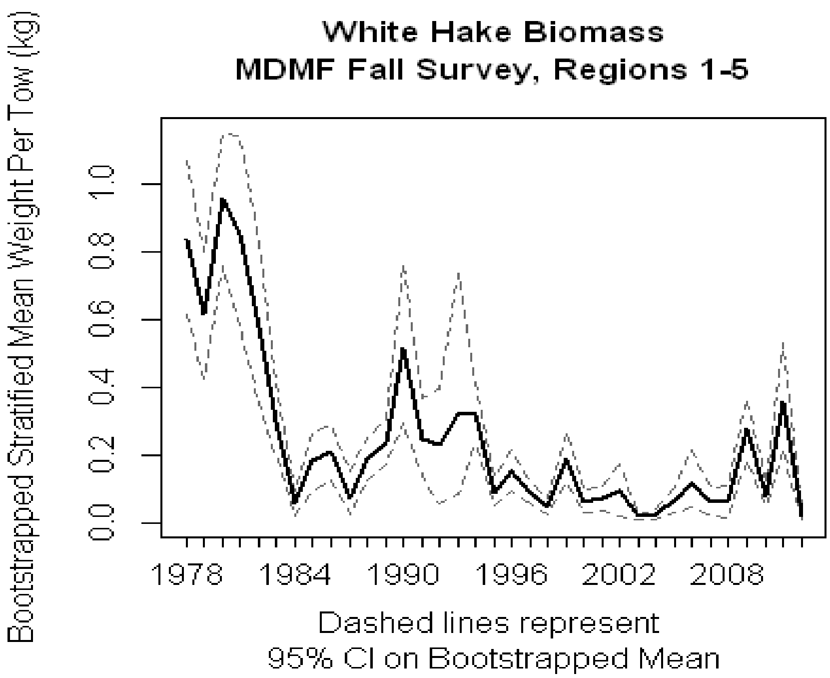


Figure B88. White hake biomass from the Massachusetts spring and fall surveys.

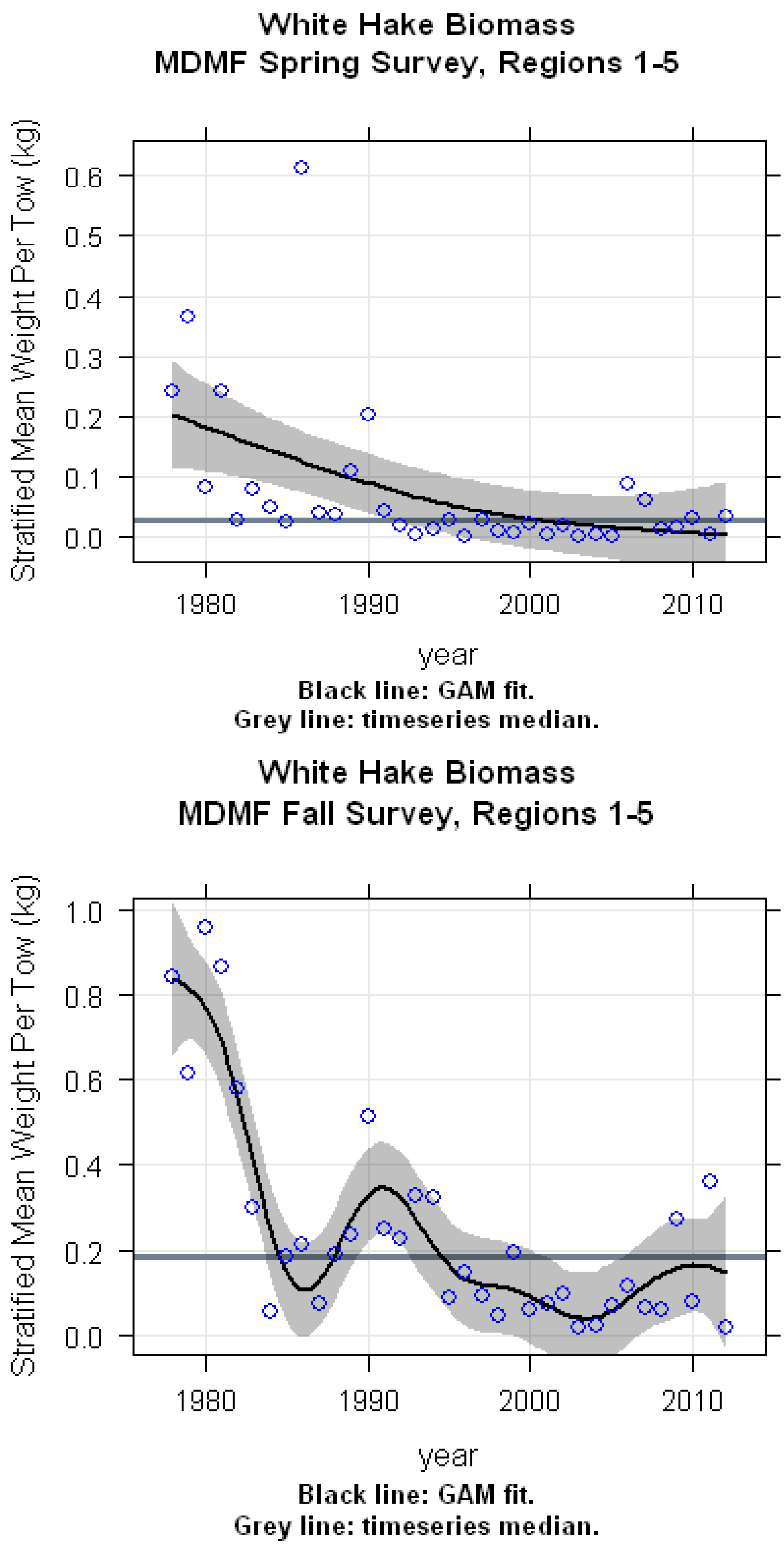
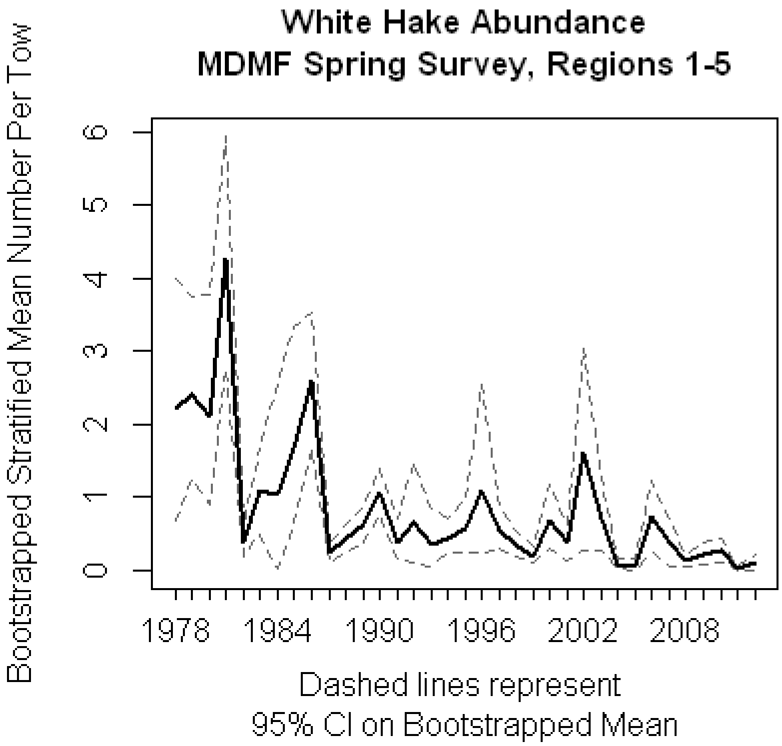


Figure B89. White hake biomass from the Massachusetts spring and fall surveys smoothed with a GAM.



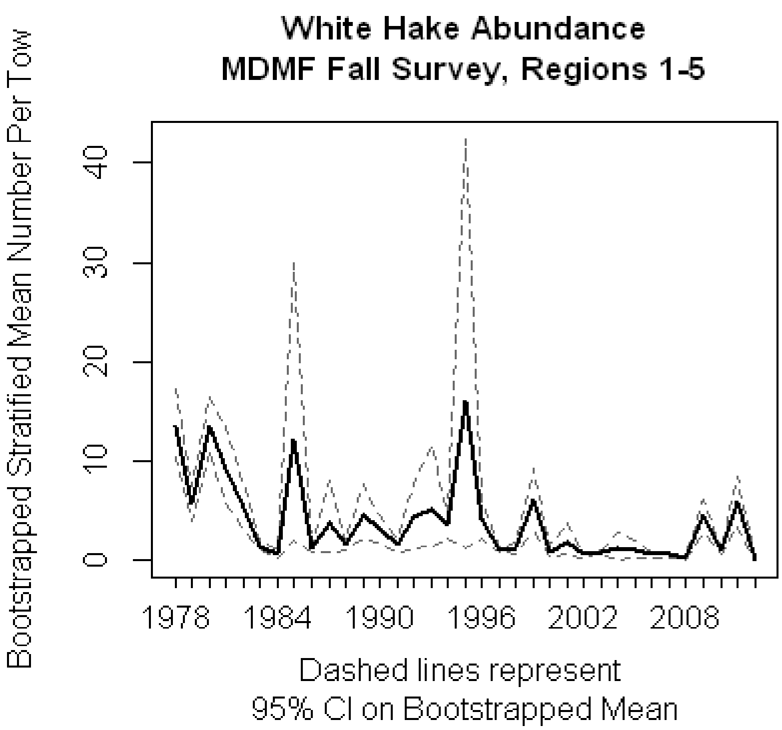


Figure B90. White hake abundance from the Massachusetts spring and fall surveys.

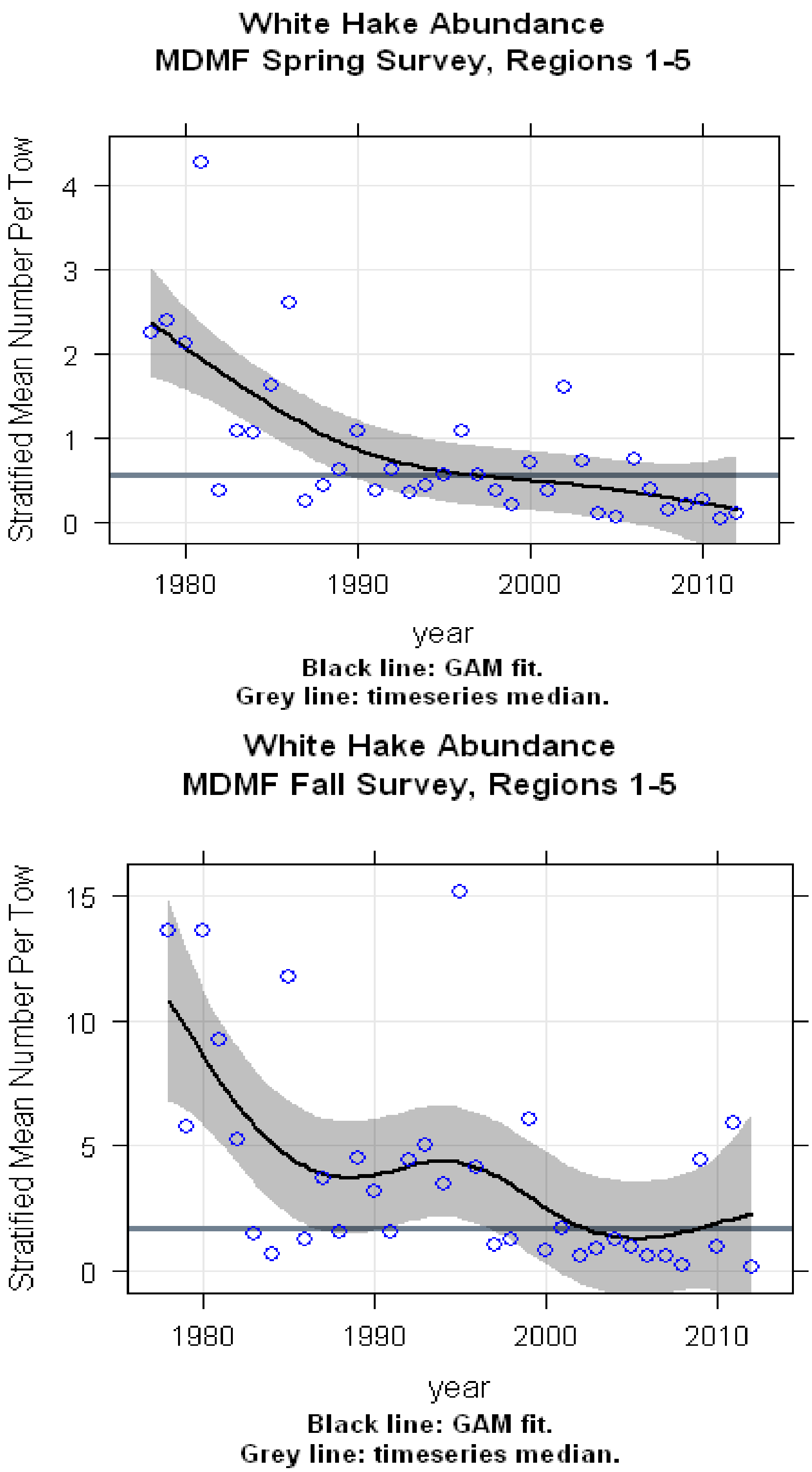


Figure B91. White hake abundance from the Massachusetts spring and fall surveys smoothed with a GAM.

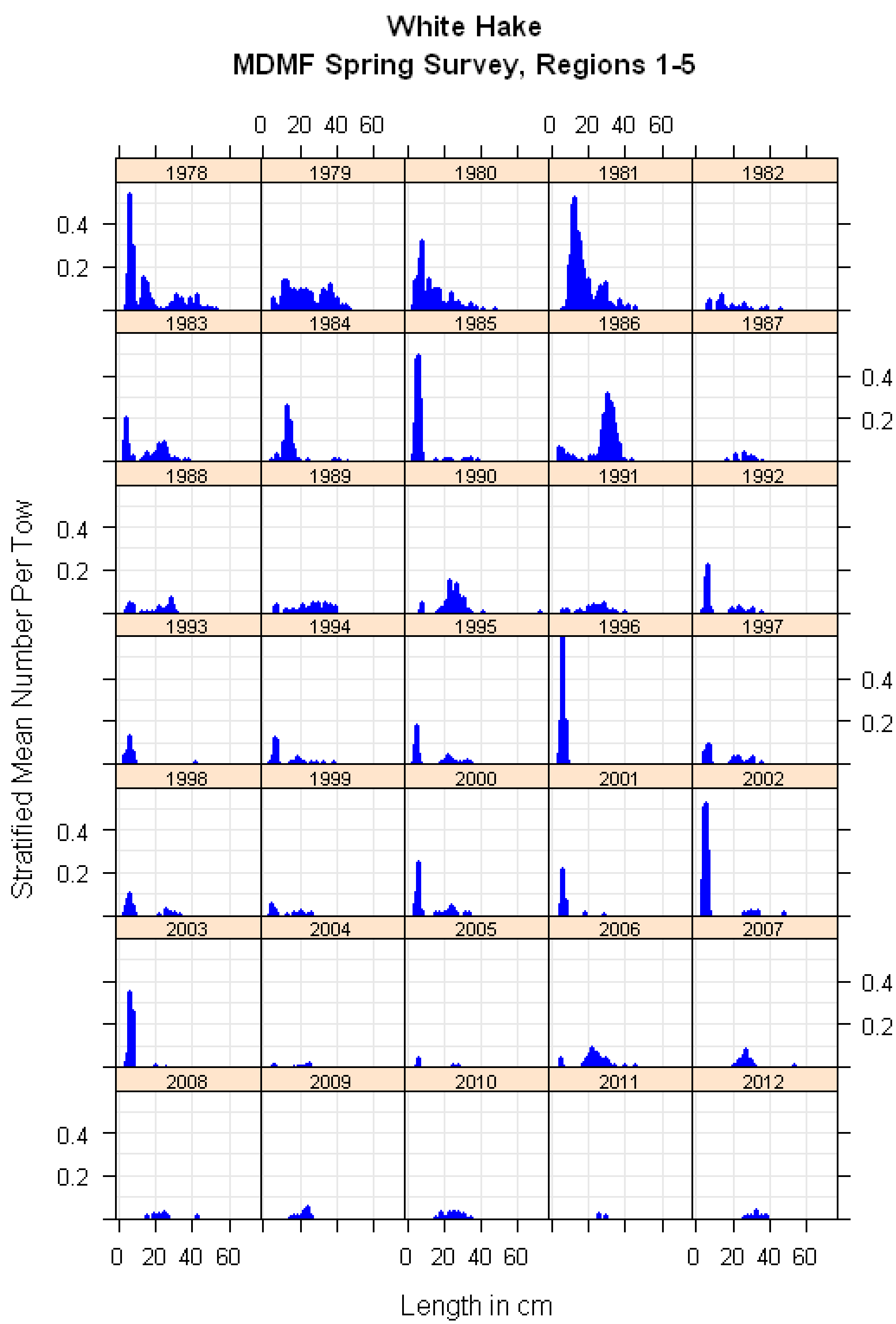


Figure B92. White hake length composition from the Massachusetts spring survey.

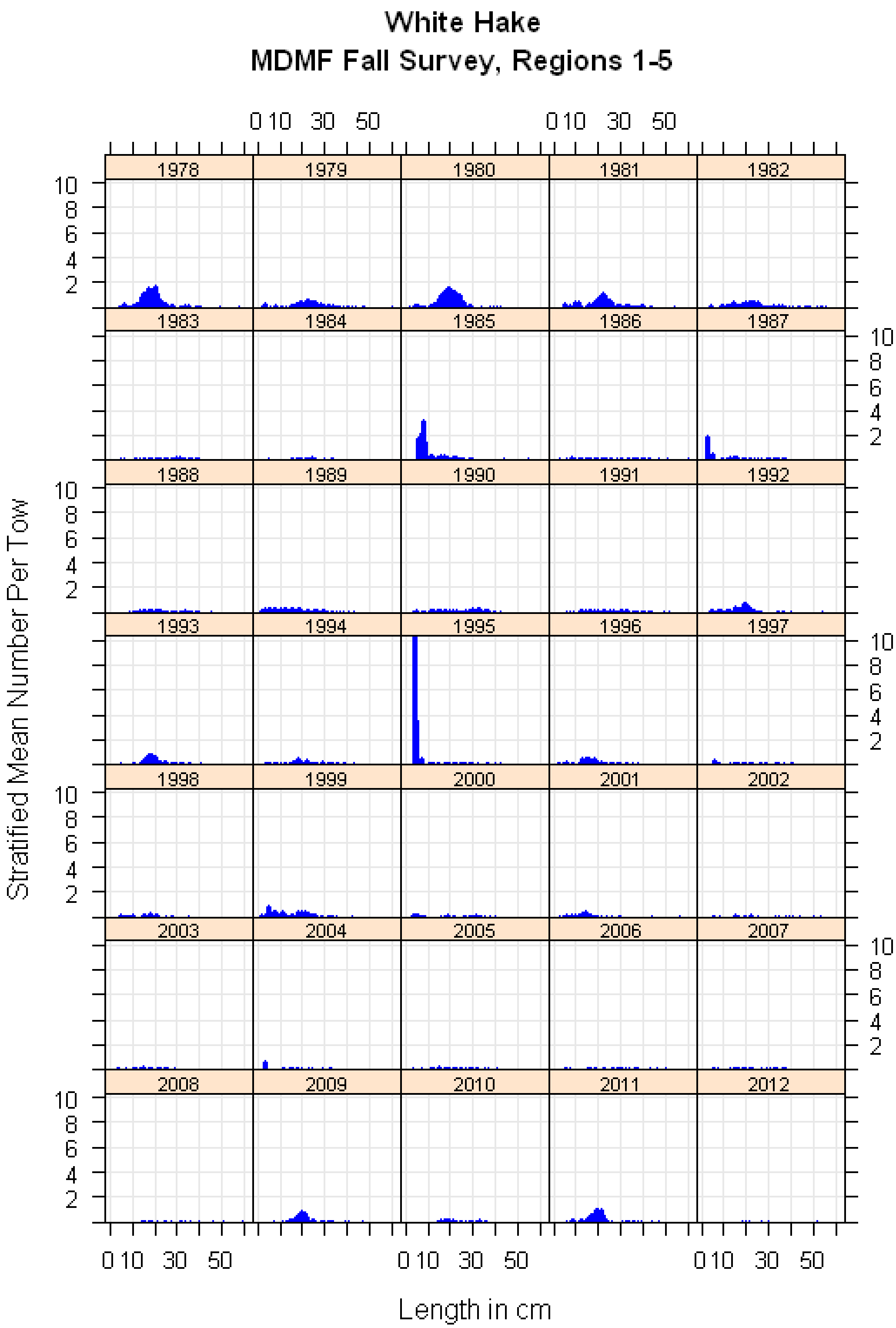


Figure B93. White hake length composition from the Massachusetts autumn survey.

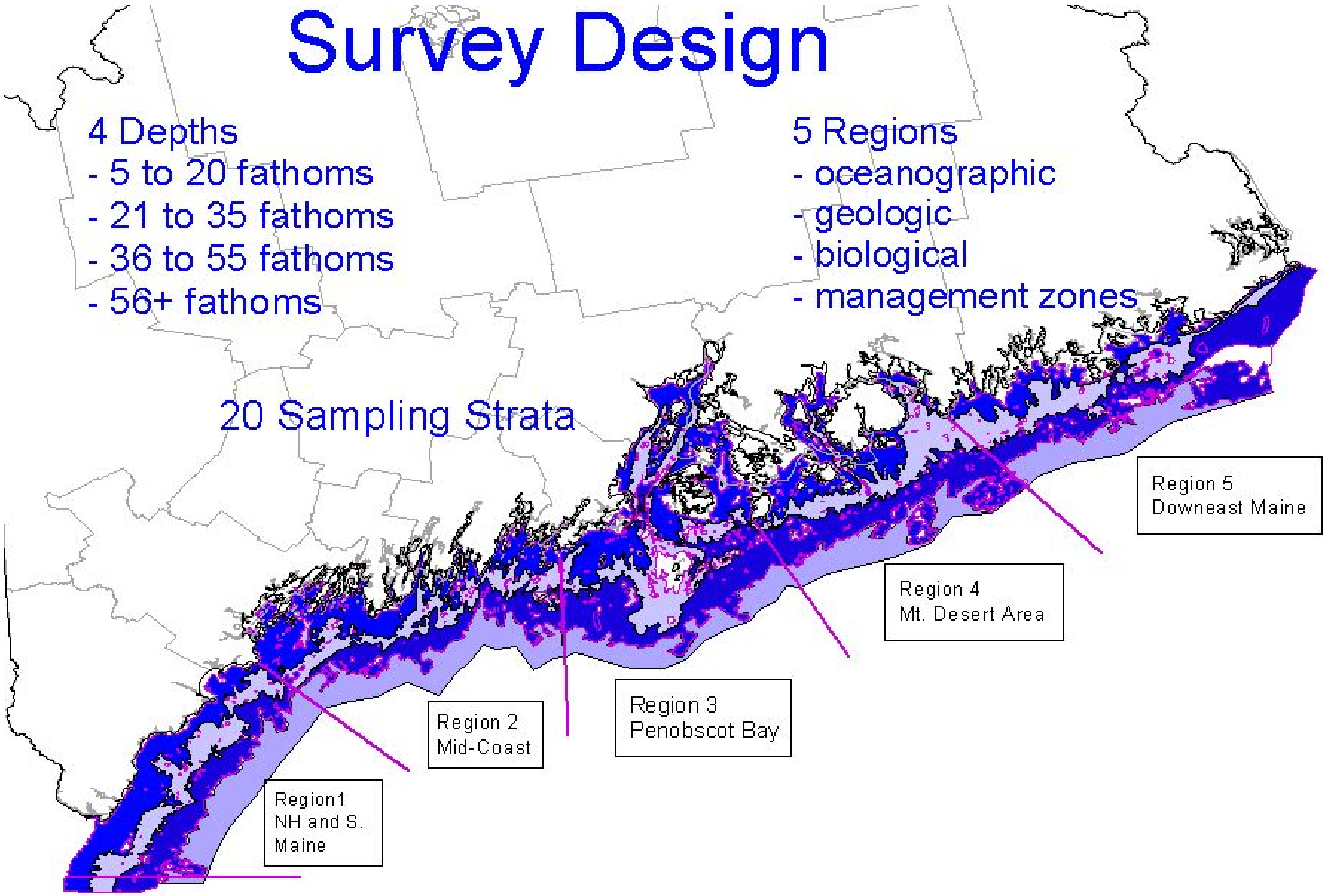


Figure B94. Survey design of the ME/NH survey.

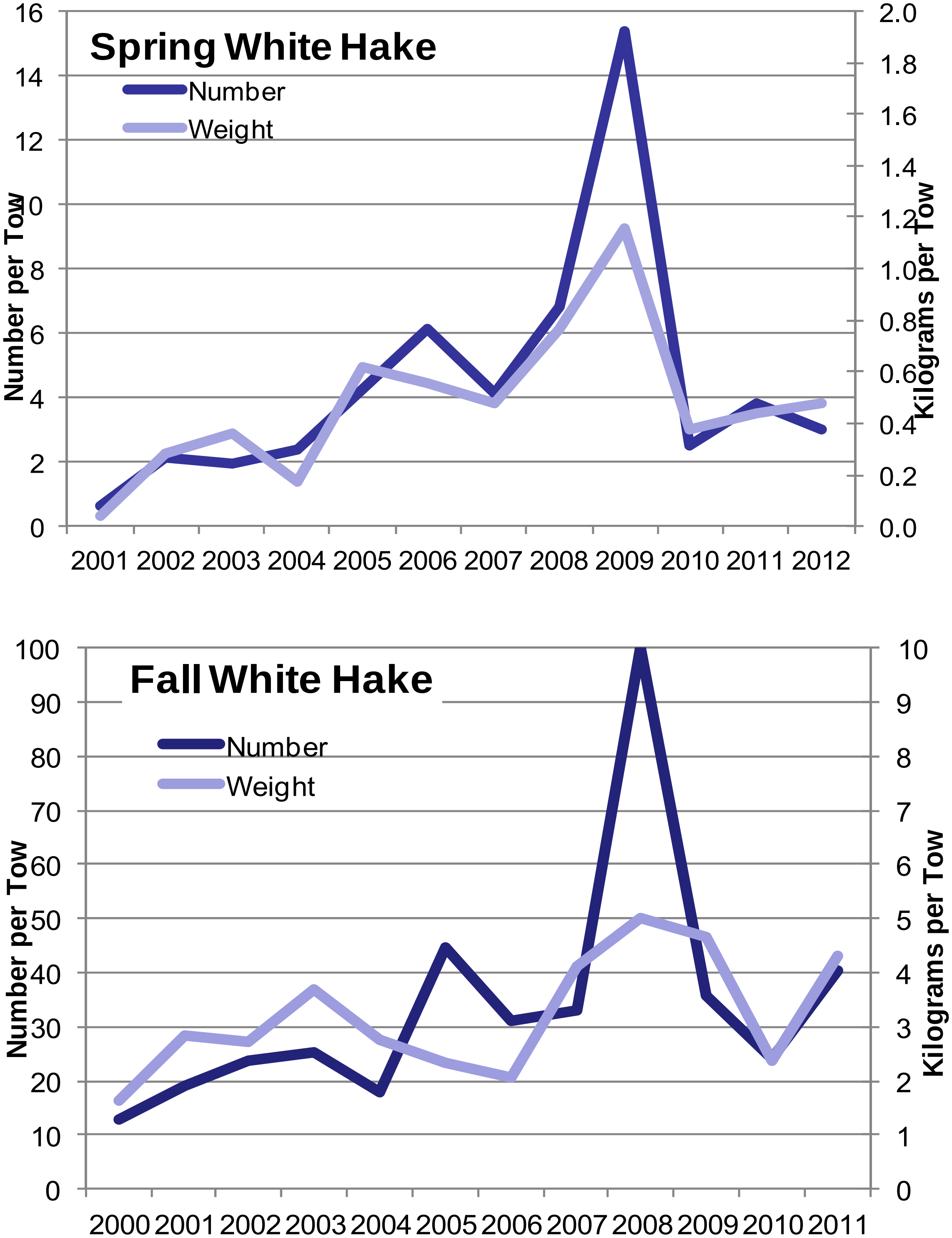


Figure B95. Abundance and biomass indices from the ME/NH spring (top panel) and autumn (bottom panel) surveys.

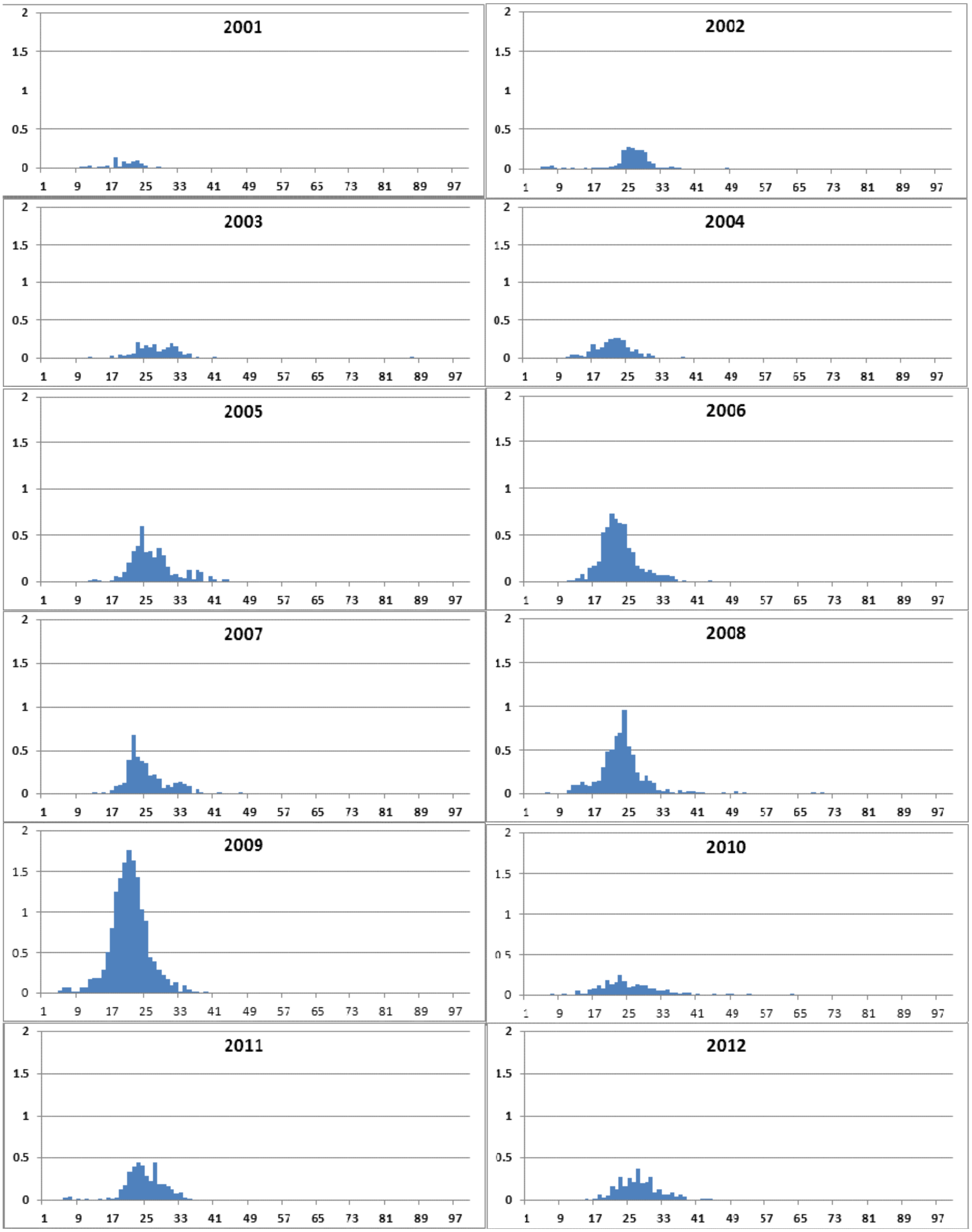


Figure B96. Length composition of the ME/NH spring survey from 2001-2012.

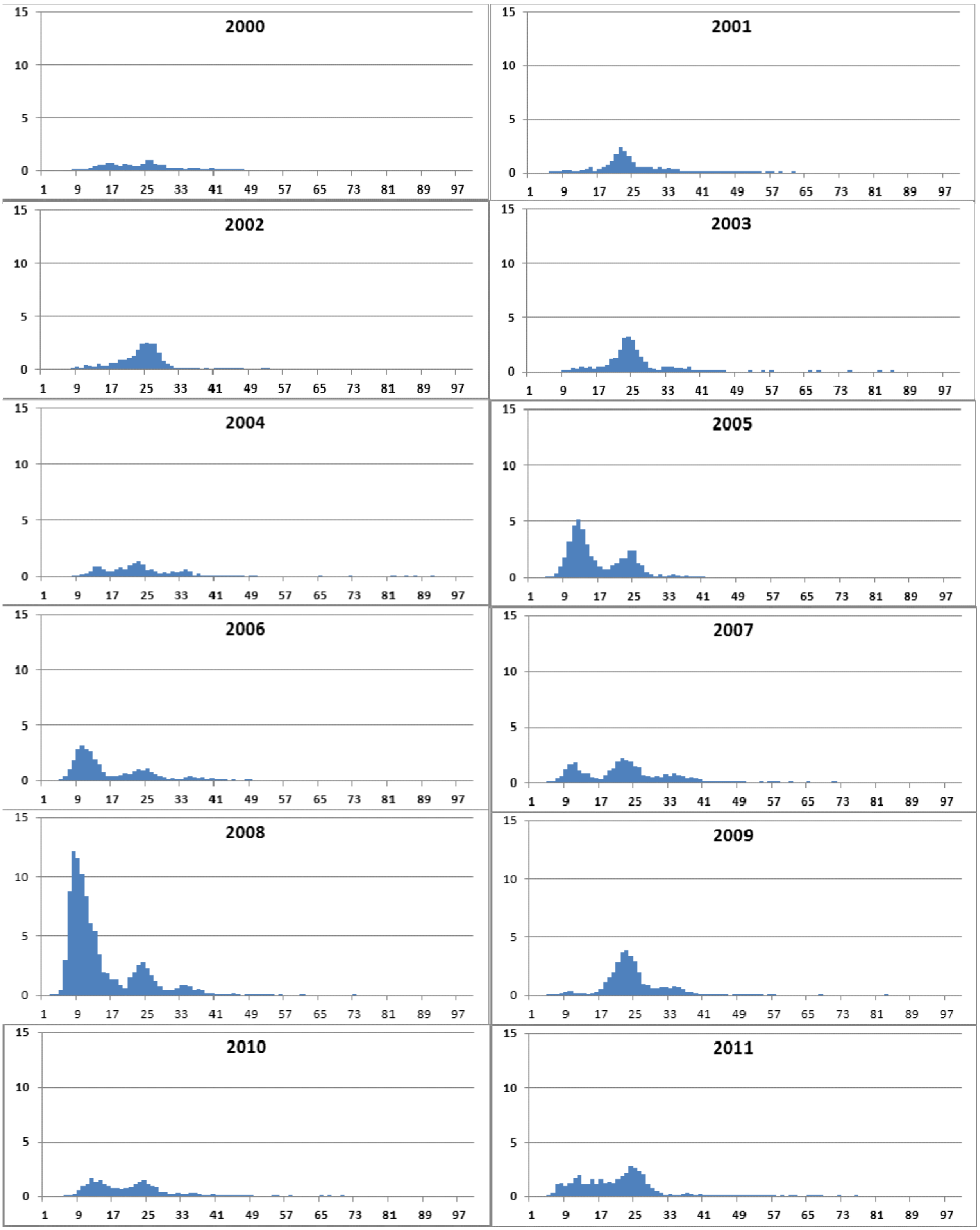


Figure B97. Length composition of the ME/NH autumn survey from 2000-2011.

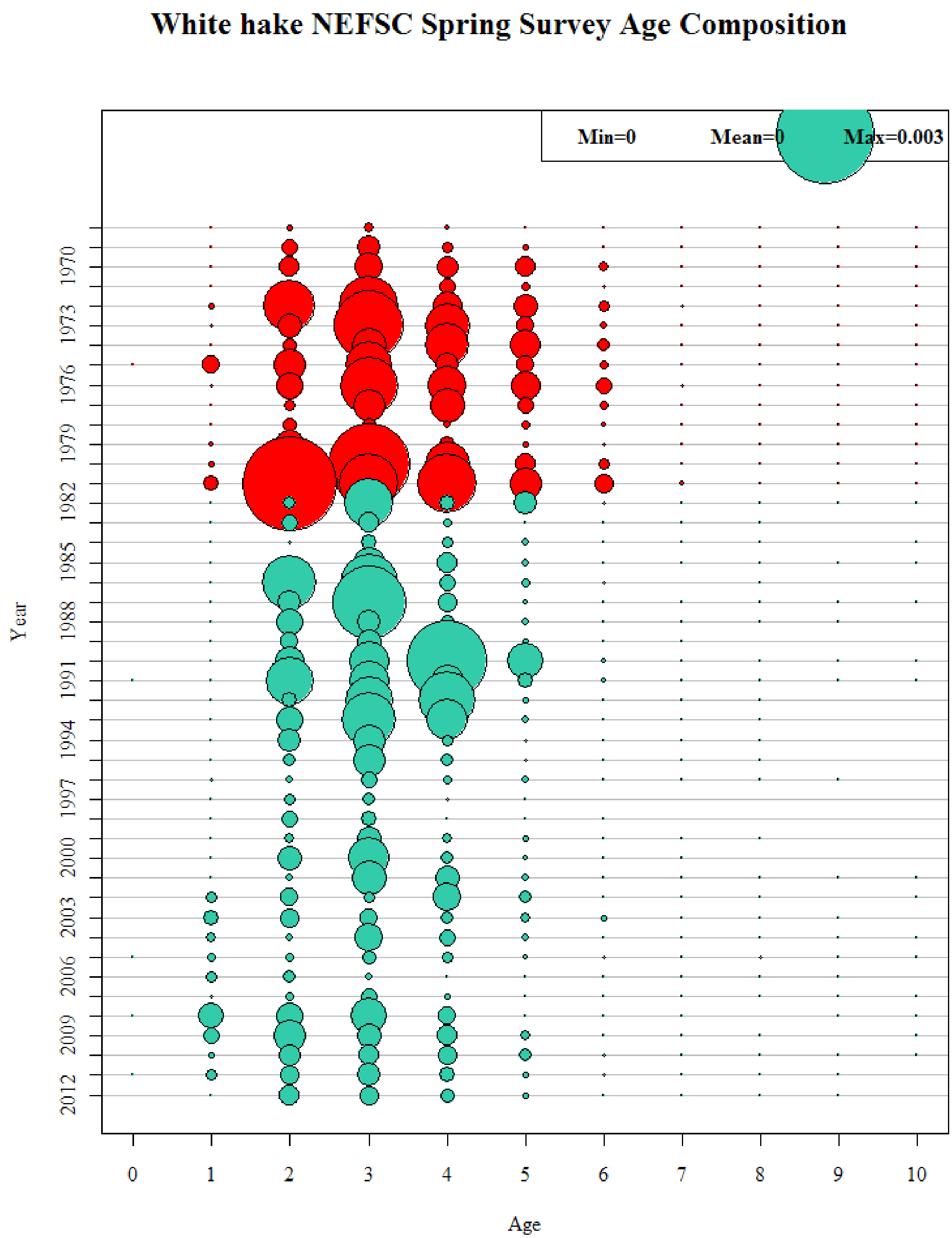


Figure B98. Age composition of the NEFSC spring survey from 1968-2012. The red bubbles indicate that a pooled ALK was used.

Figure B99. Age composition of the NEFSC autumn survey from 1963-2011. The red bubbles indicate that a pooled ALK was used.

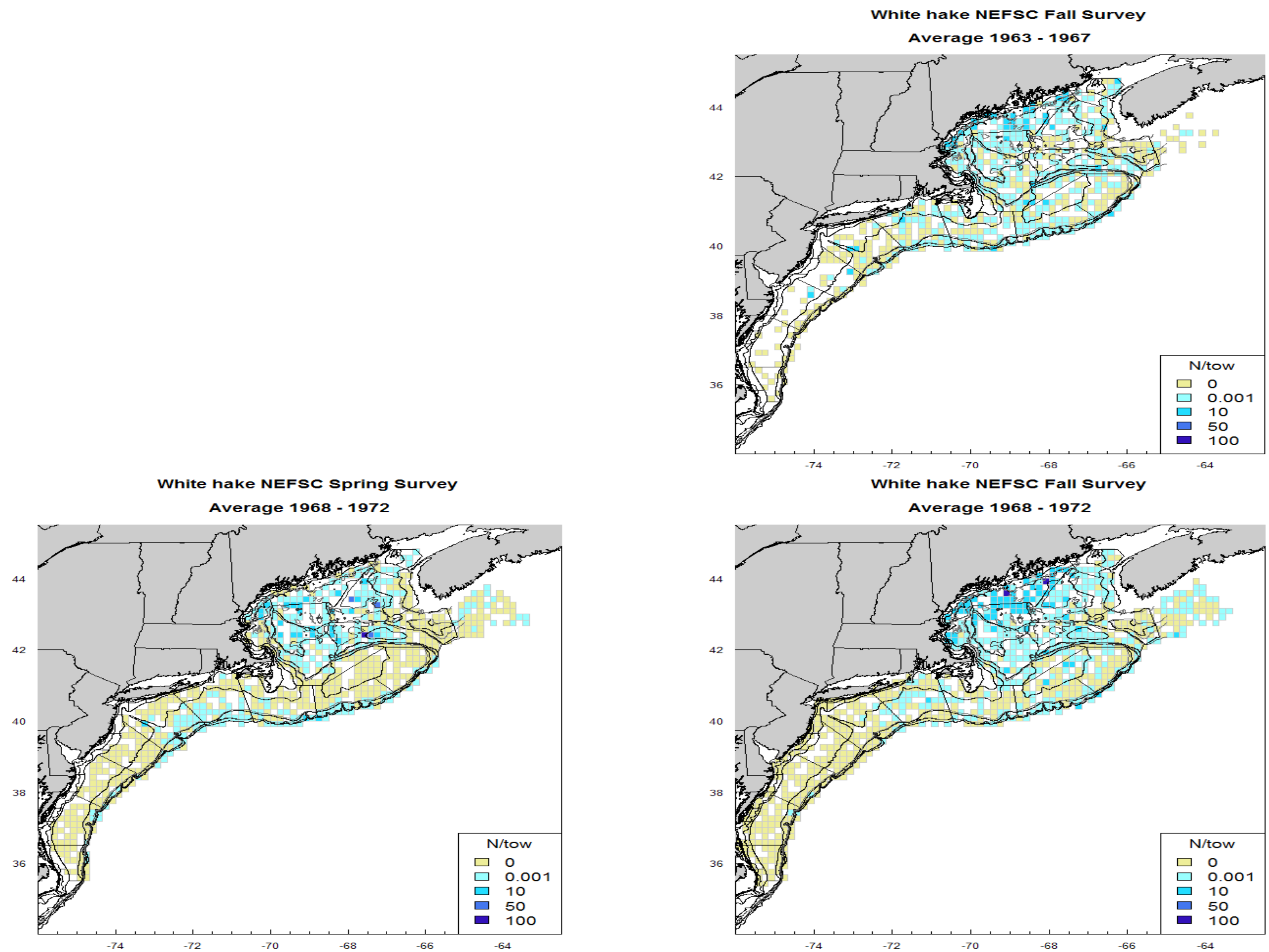


Figure B100a. Distribution of white hake number/tow from the NEFSC spring and autumn surveys from 1963-1972.

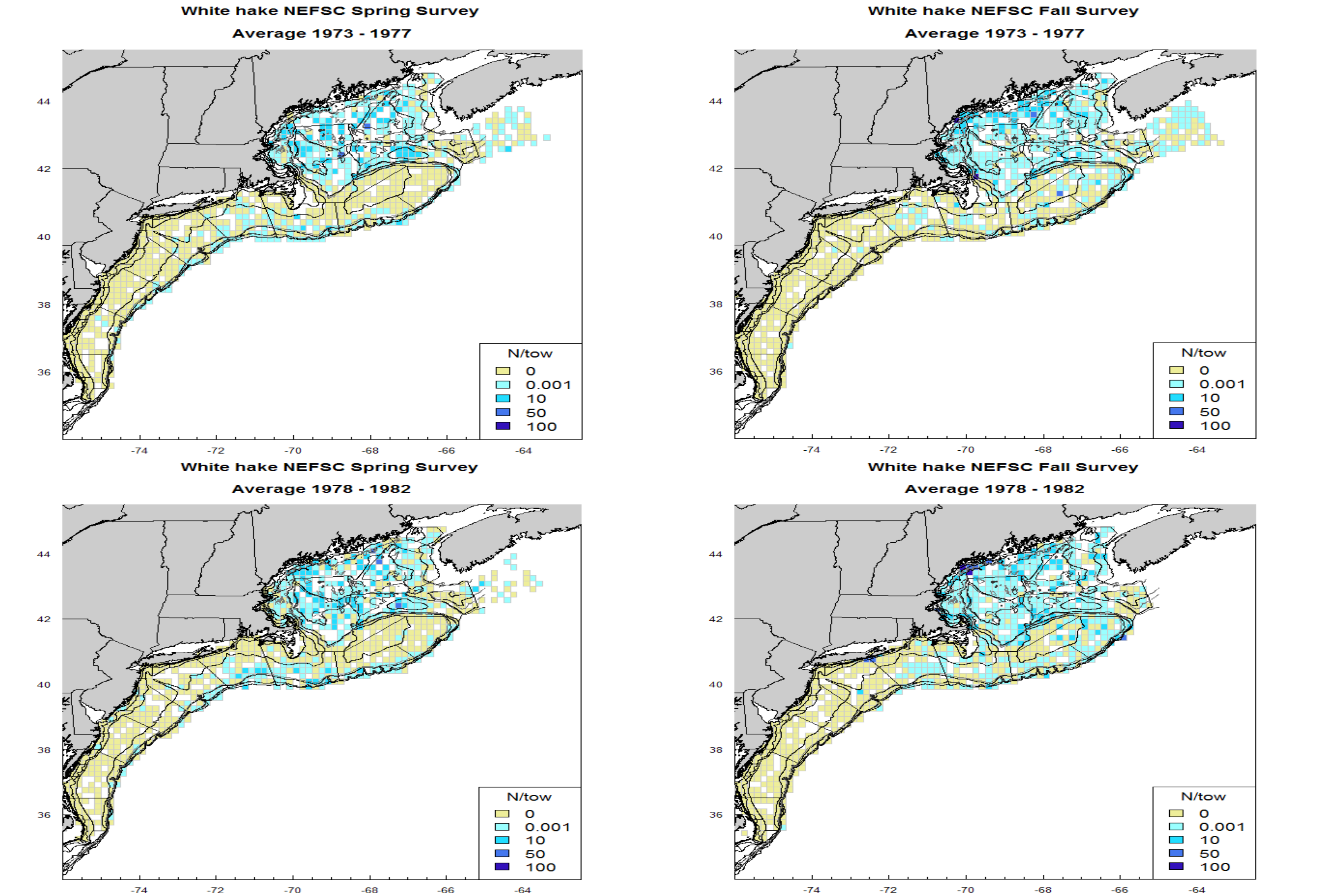


Figure B100b. Distribution of white hake in number/tow from the NEFSC spring and autumn surveys from 1973-1982.

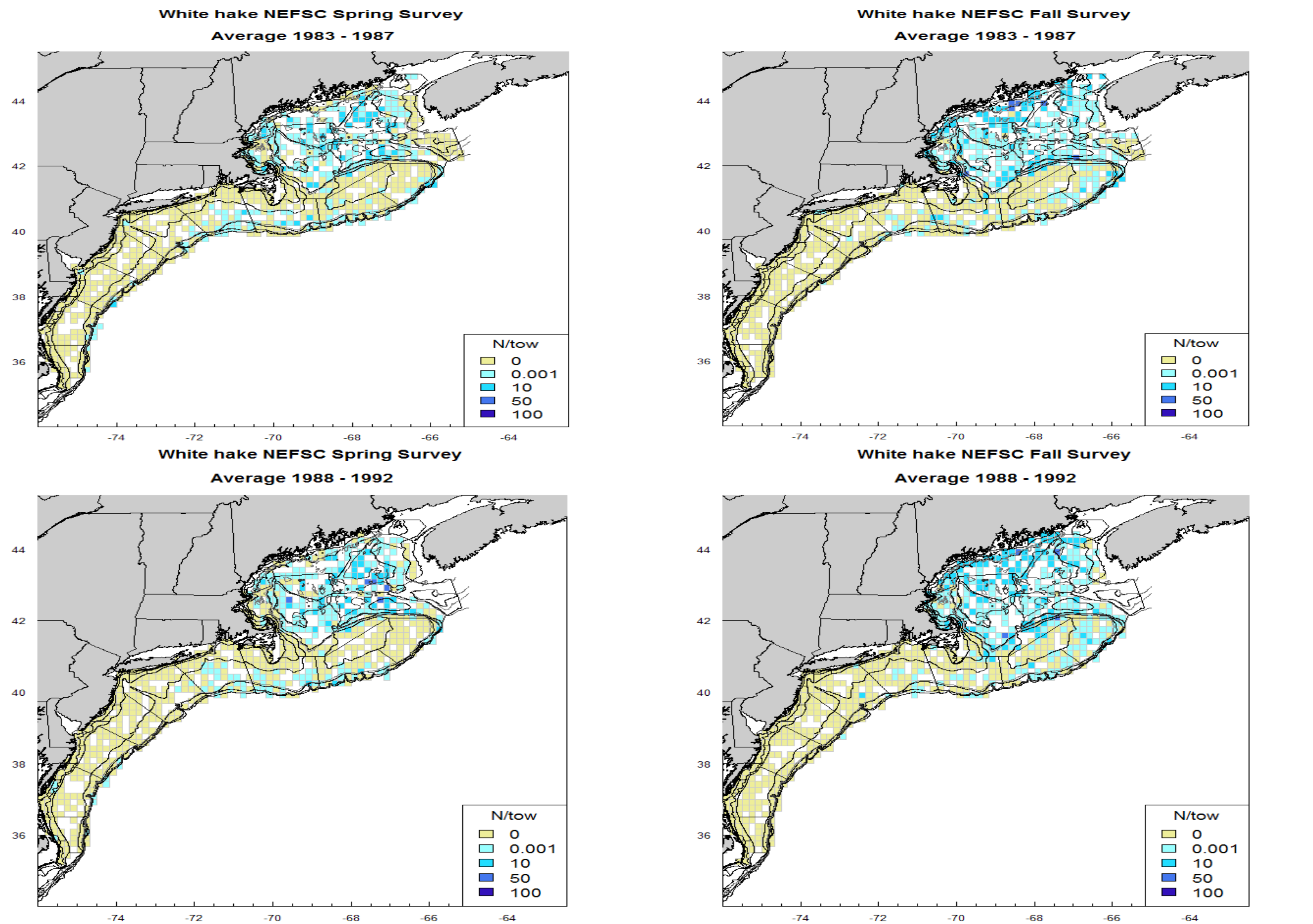


Figure B100c. Distribution of white hake in number/tow from the NEFSC spring and autumn surveys from 1983-1992.

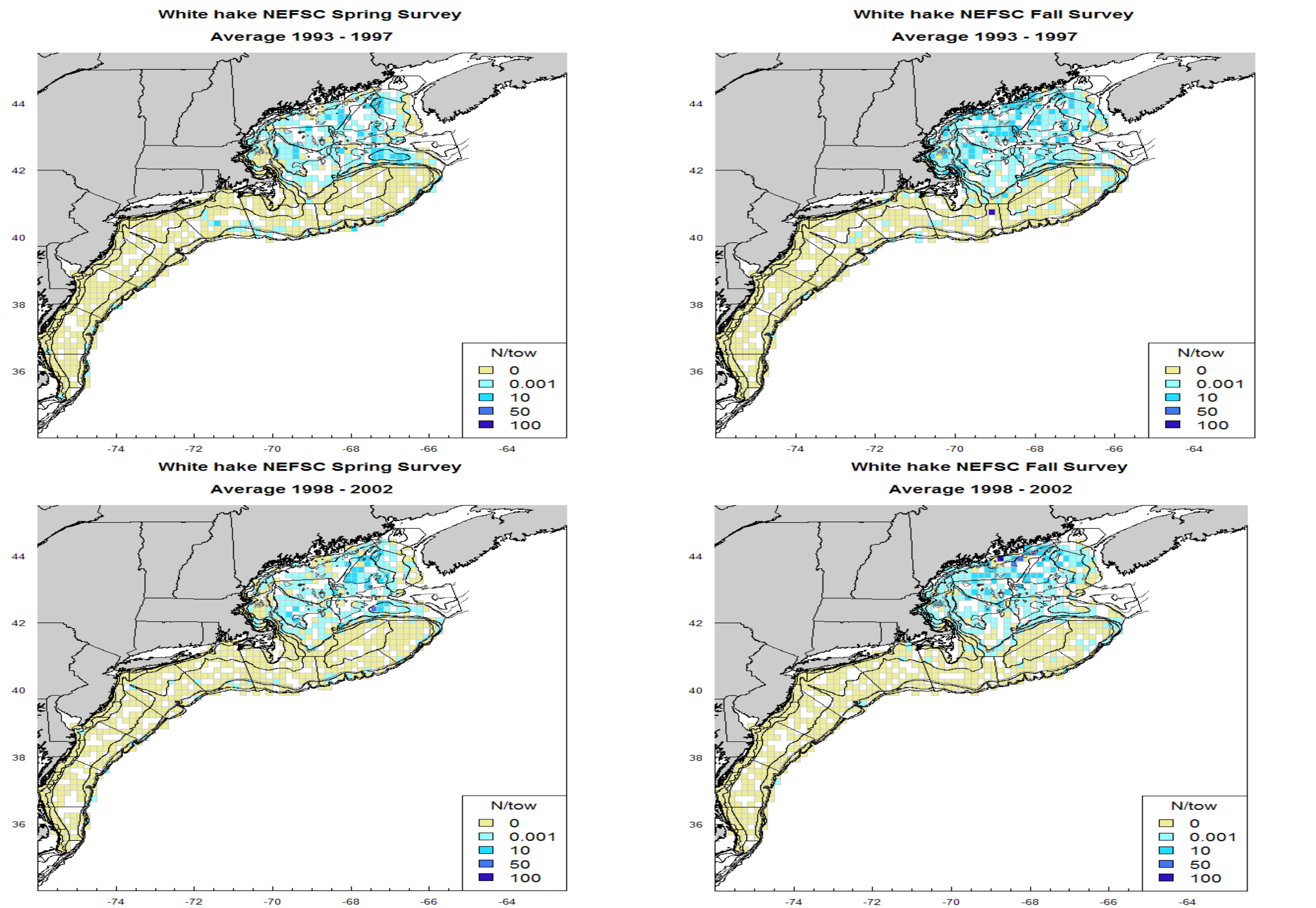


Figure B100d. Distribution of white hake in number/tow from the NEFSC spring and autumn surveys from 1993-2002.

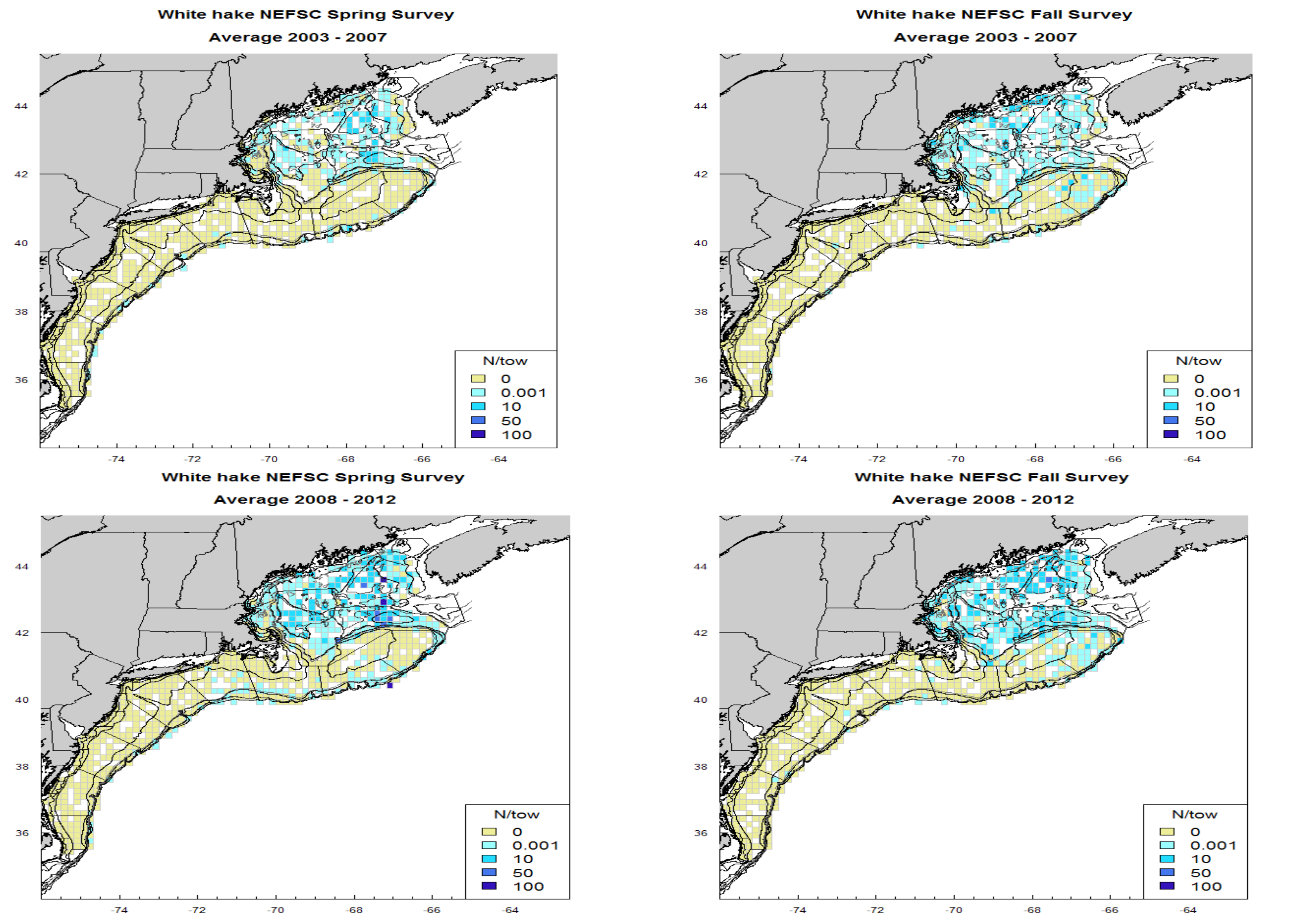


Figure B100e. Distribution of white hake from the NEFSC spring and autumn surveys from 2003-2012.

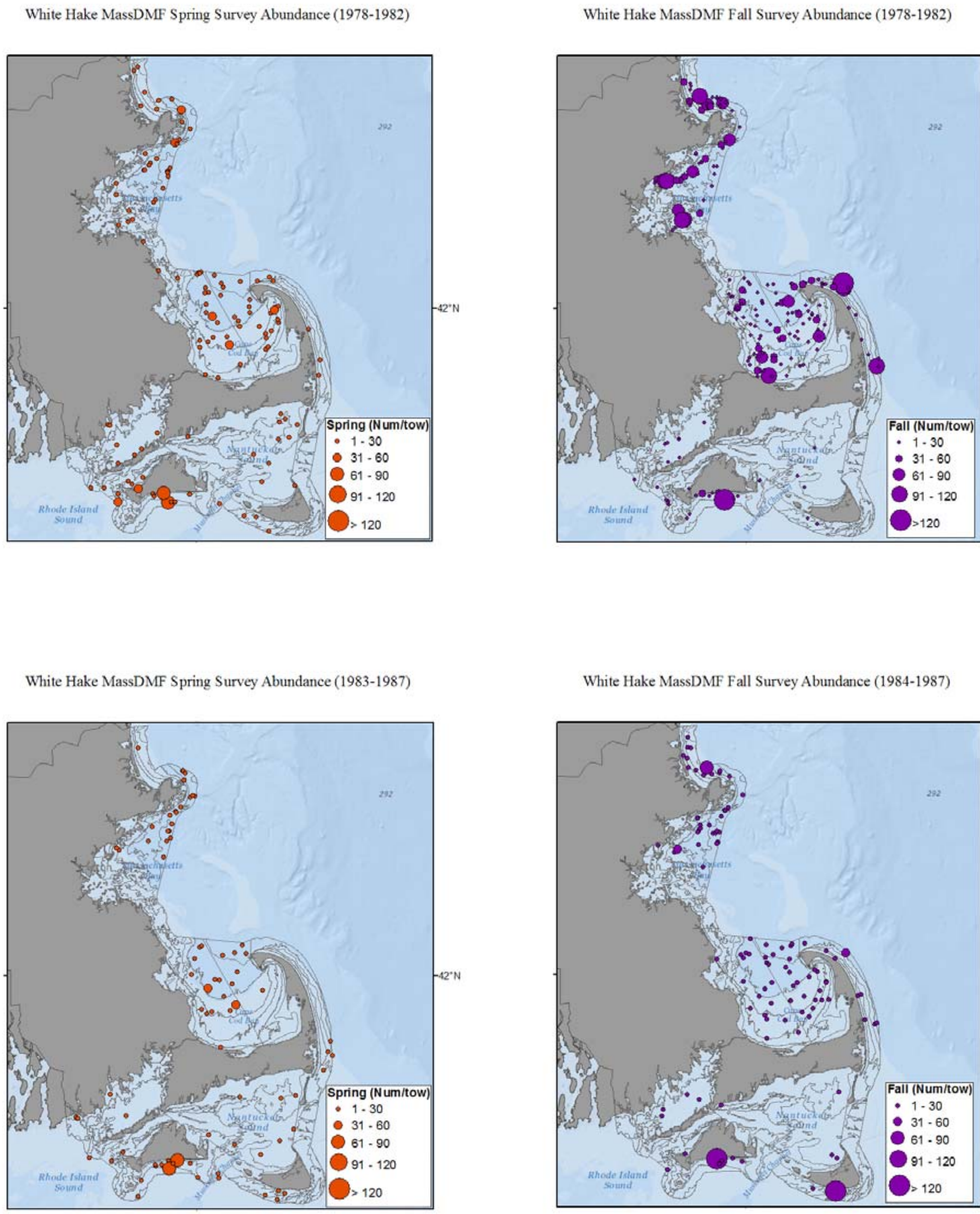


Figure B101a. Distribution of white hake in number/tow from the MADMF spring and autumn surveys from 1978-1987.

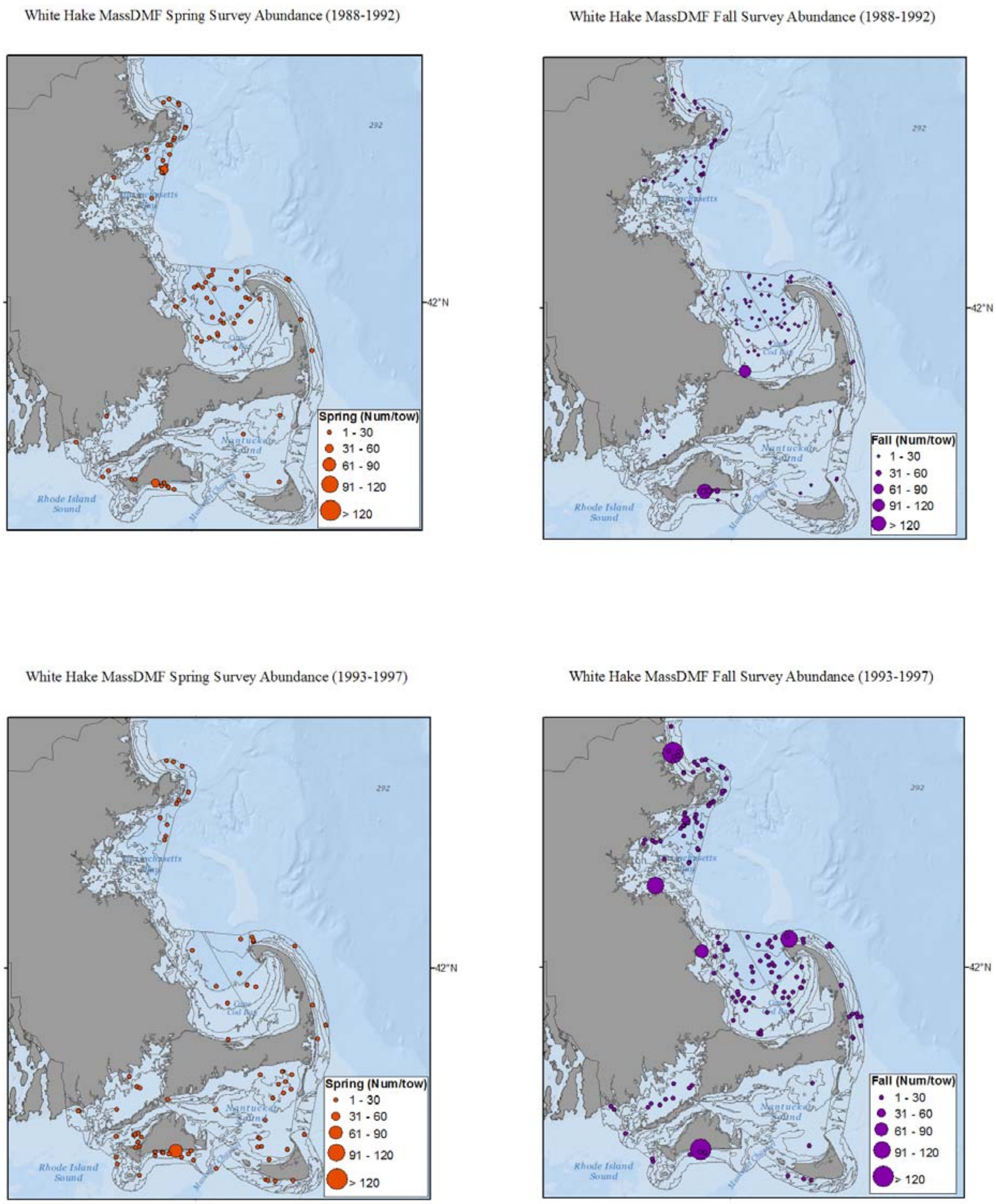


Figure B101b. Distribution of white hake in number/tow from the MADMF spring and autumn surveys from 1988-1997.

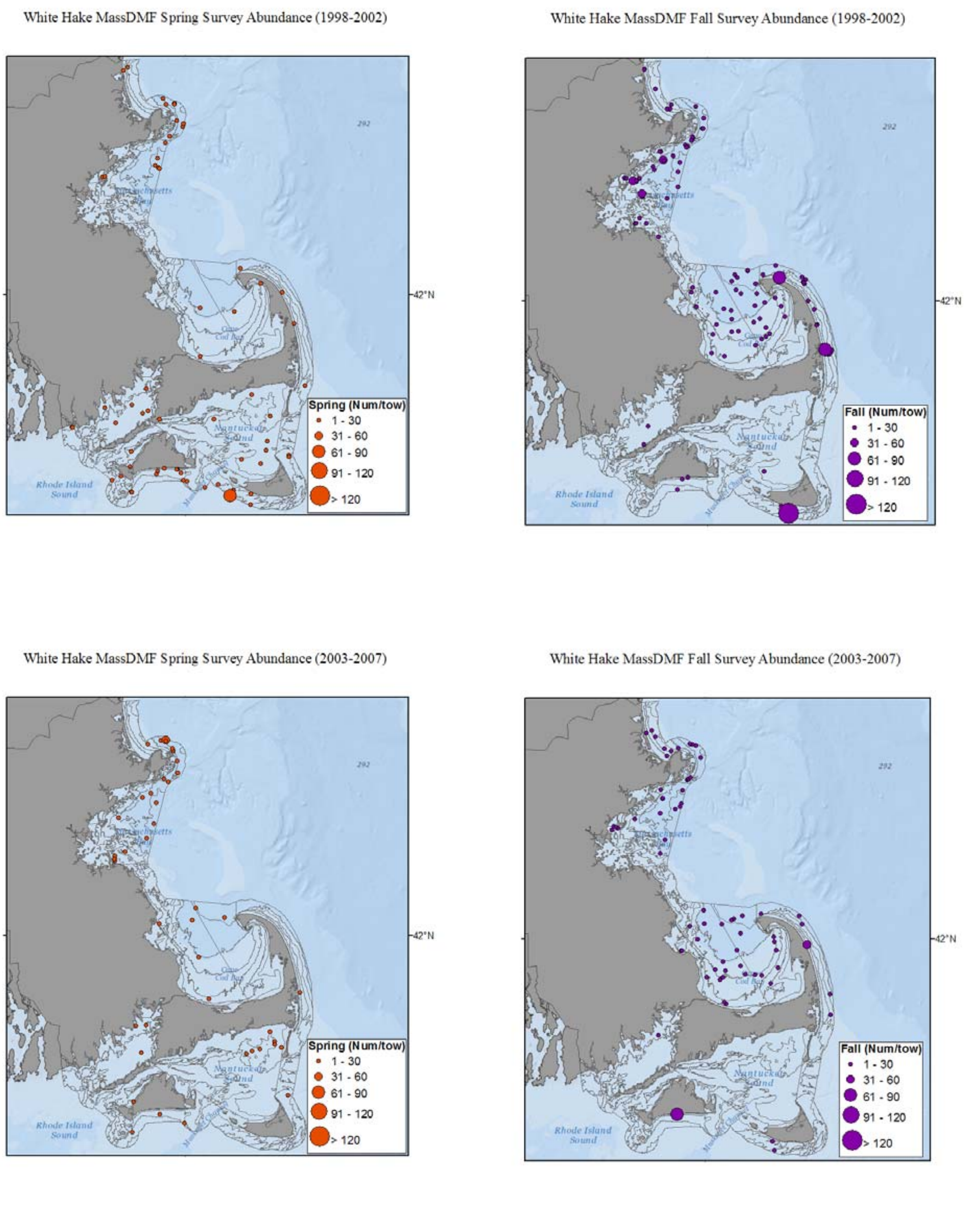


Figure B101c. Distribution of white hake in number/tow from the MADMF spring and autumn surveys from 1998-2007.

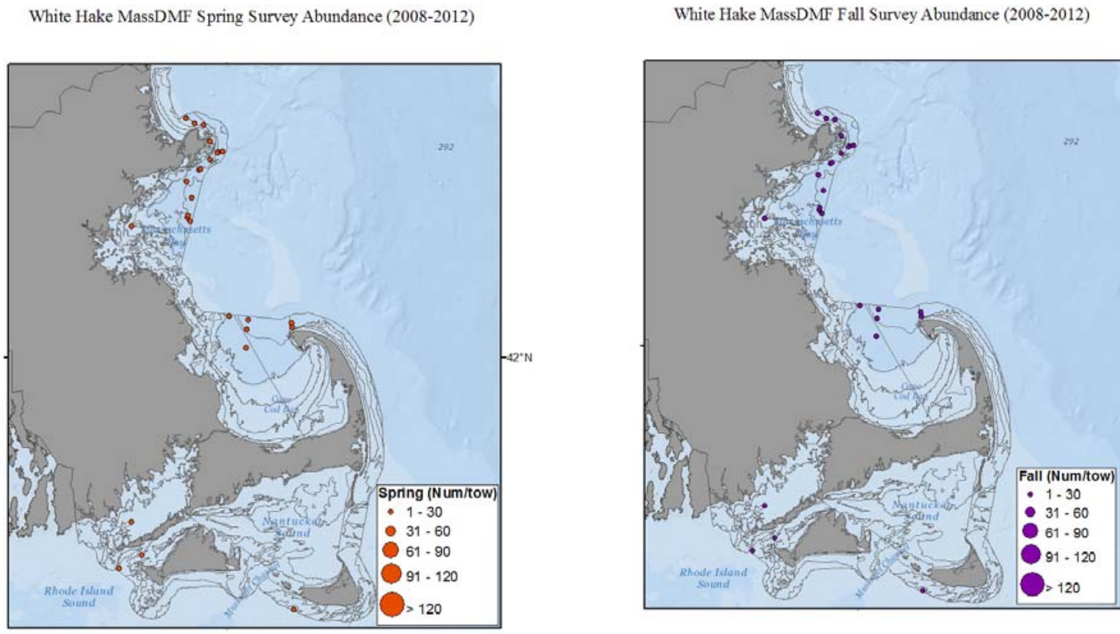


Figure B101d. Distribution of white hake in number/tow from the MADMF spring and autumn surveys from 2008-2012.

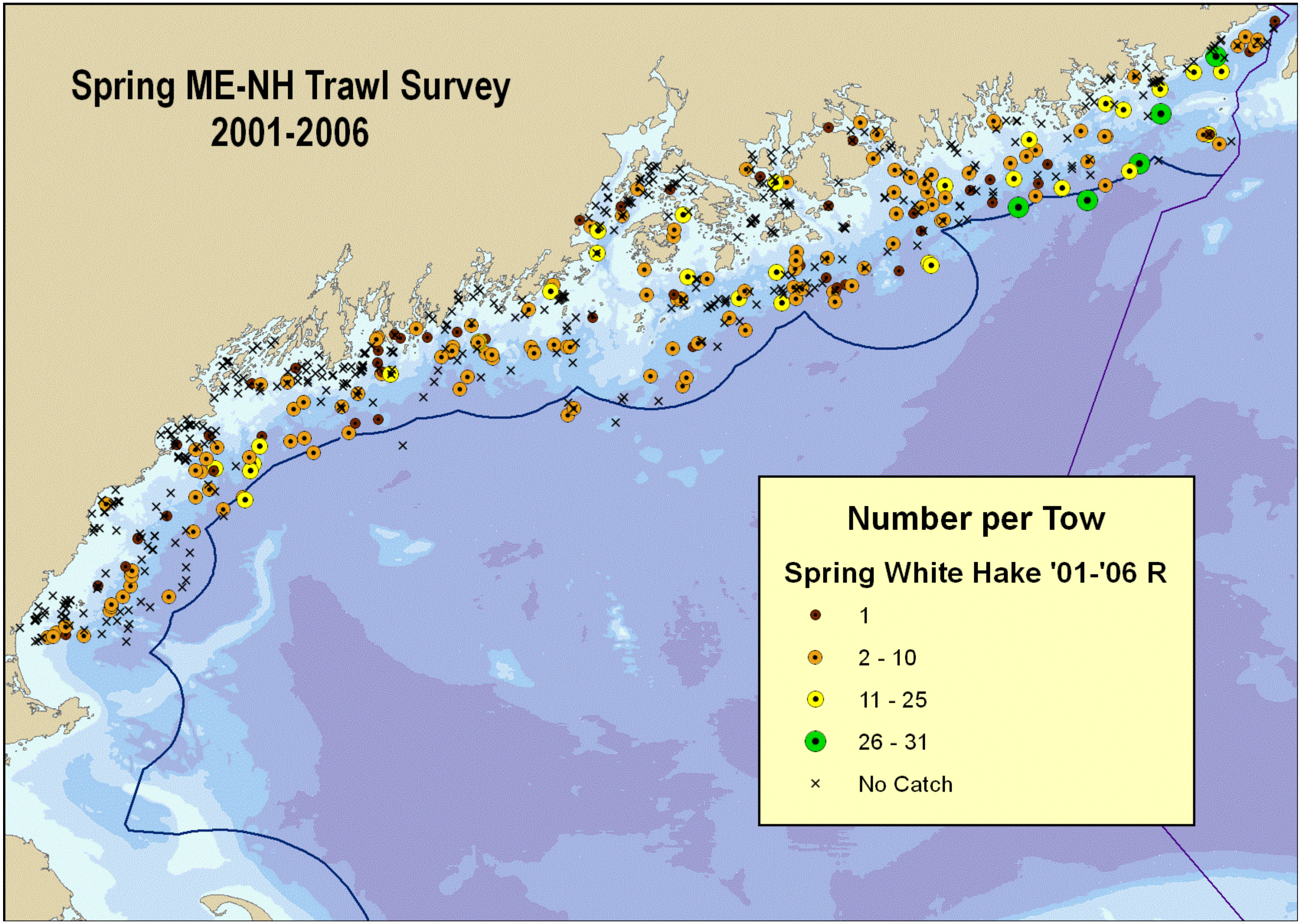


Figure B102a. Distribution of white hake in number/tow from the ME/NH spring surveys from 2001-2006.

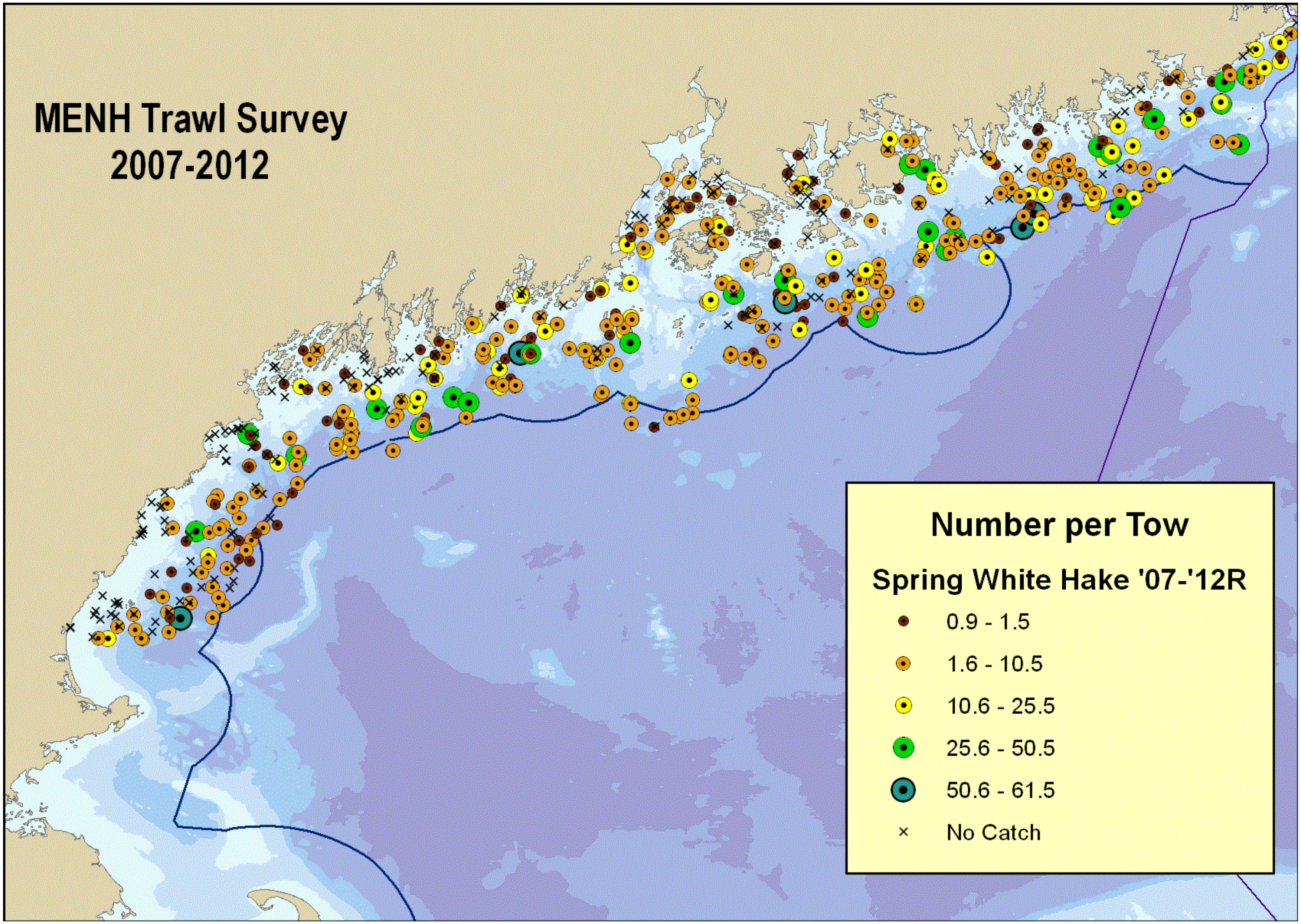


Figure B102b. Distribution of white hake in number/tow from the ME/NH spring surveys from 2007-2012.

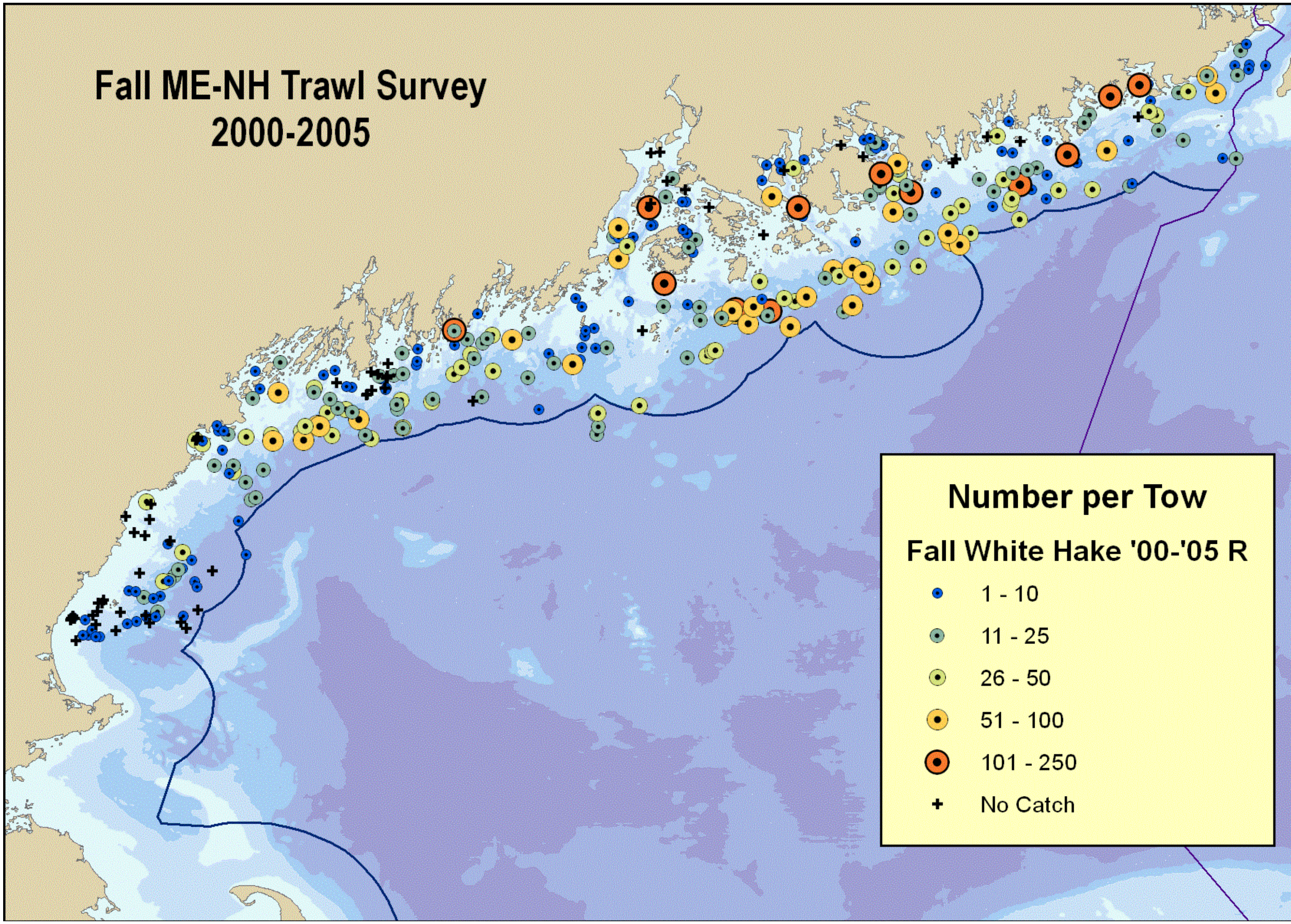


Figure B103. Distribution of white hake in number/tow from the ME/NH autumn surveys from 2000-2005.

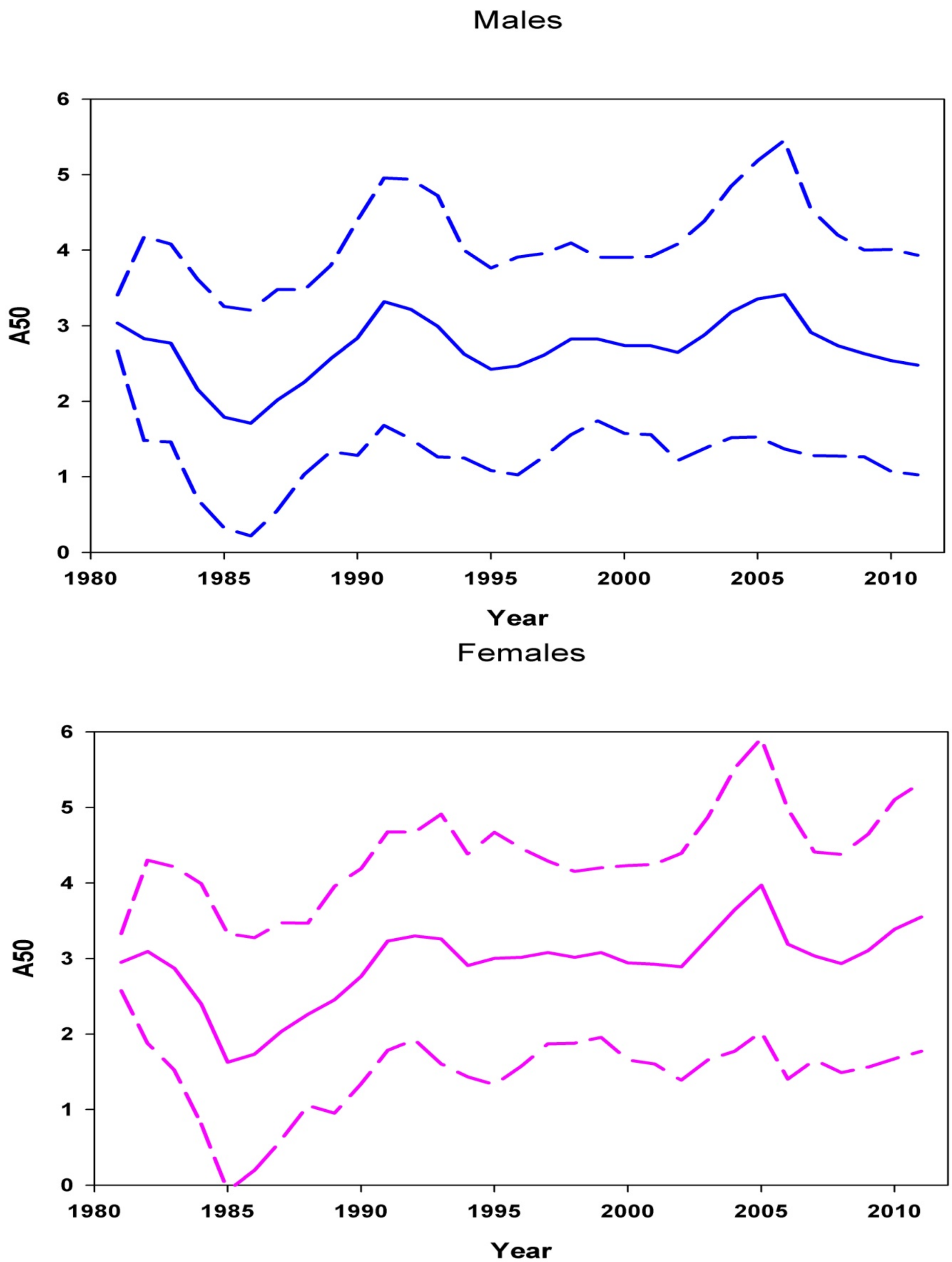
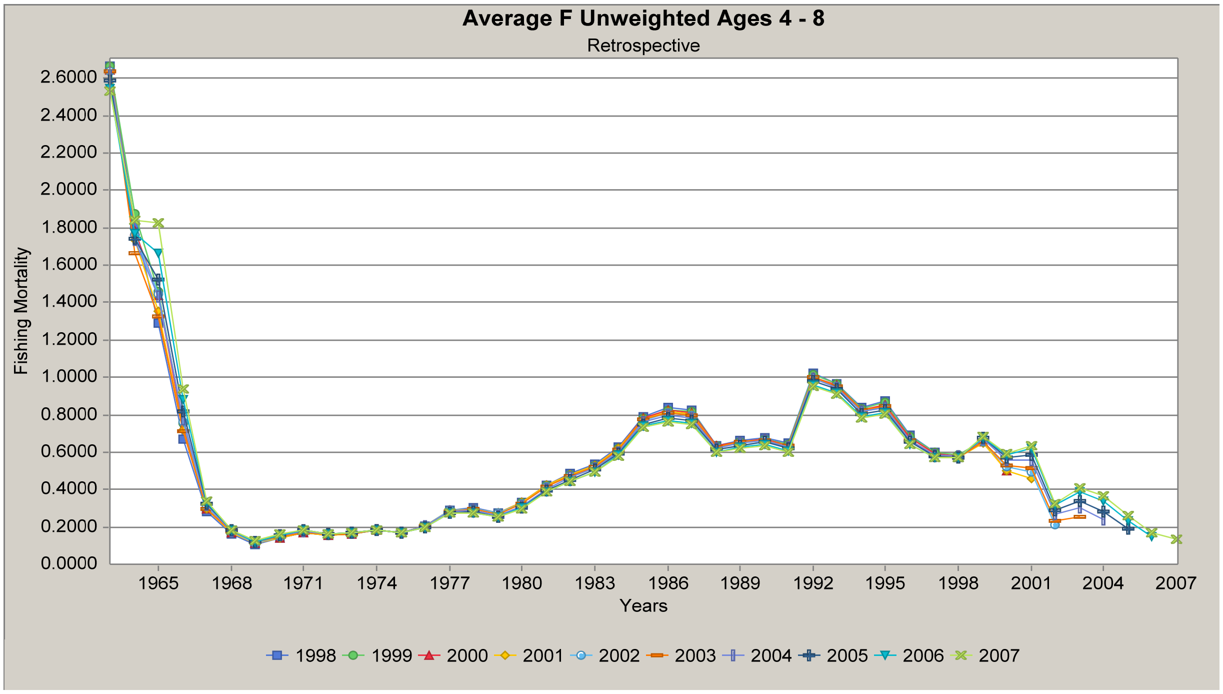


Figure B104. Three-year moving averages of the average age-at-50% maturity (A50) and corresponding 95% confidence intervals for male (top panel) and female (bottom panel) white hake from 1982 to 2011.



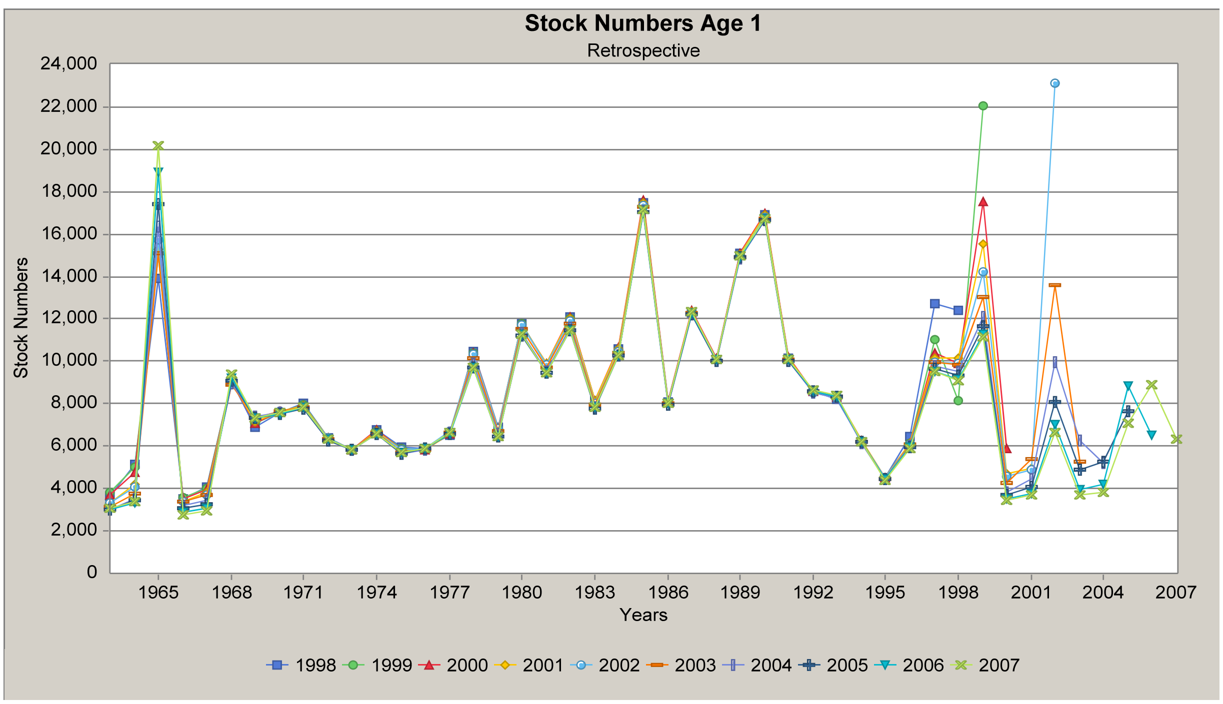


Figure B105. Estimates of fishing mortality (top panel) and recruitment (bottom panel) from the GARM III BRP meeting ASAP run.

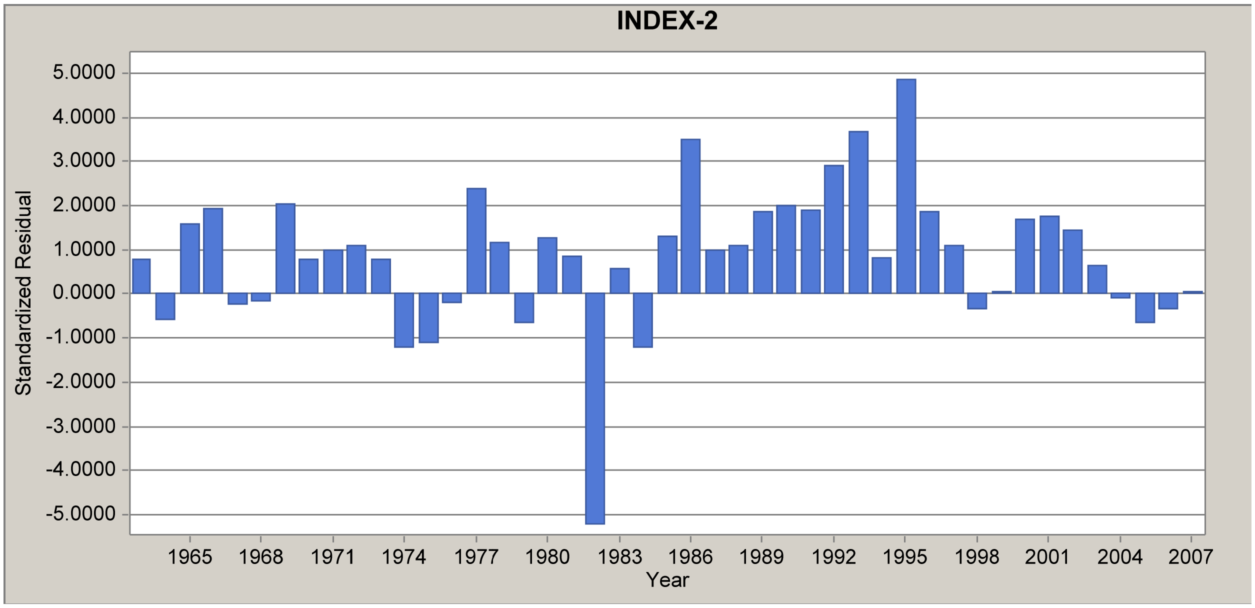


Figure B106. Residual pattern from the autumn survey GARM III BRP meeting ASAP run.

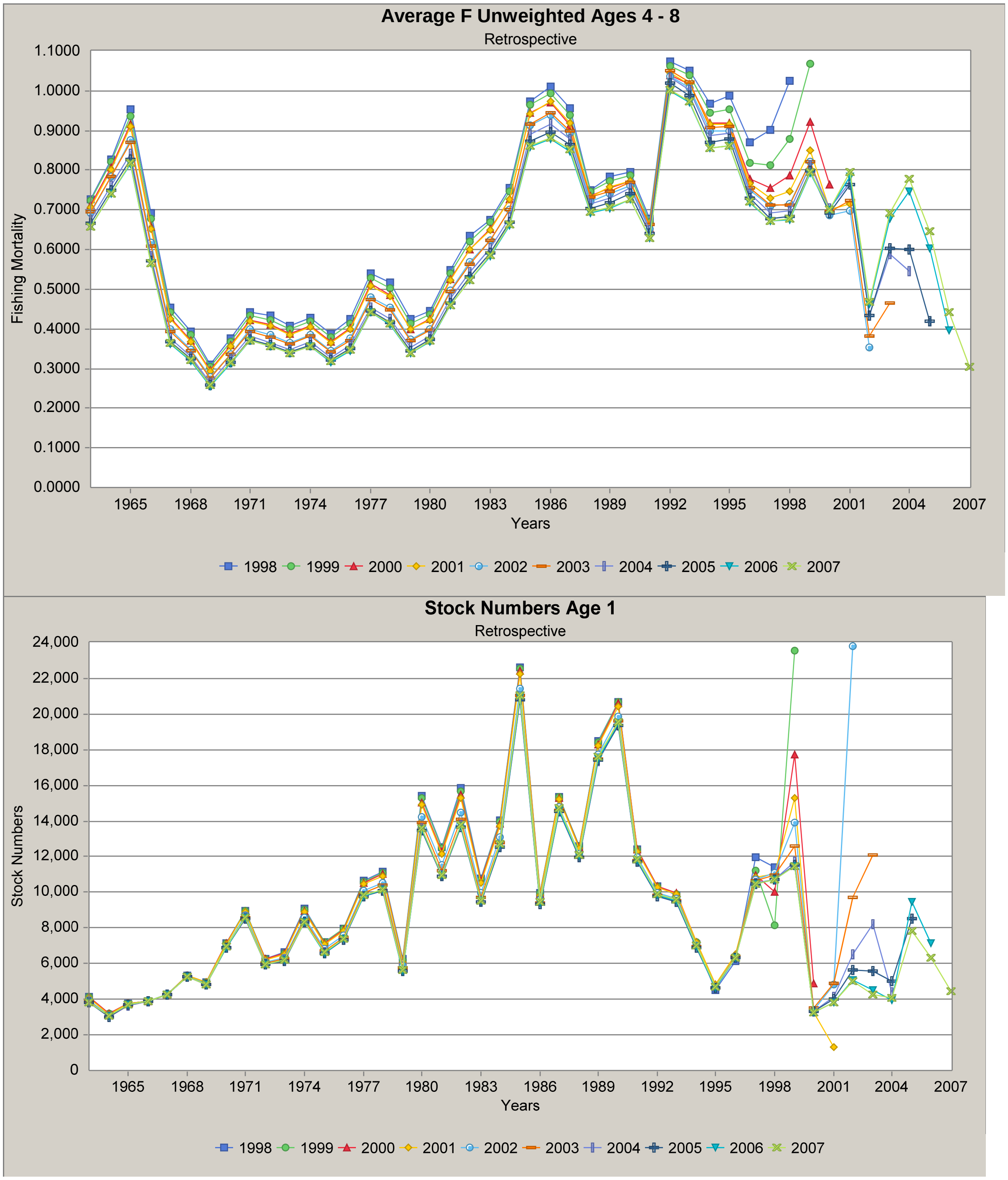


Figure B107. Estimates of fishing mortality (top panel) and recruitment (bottom panel) from the GARM III final meeting ASAP run.

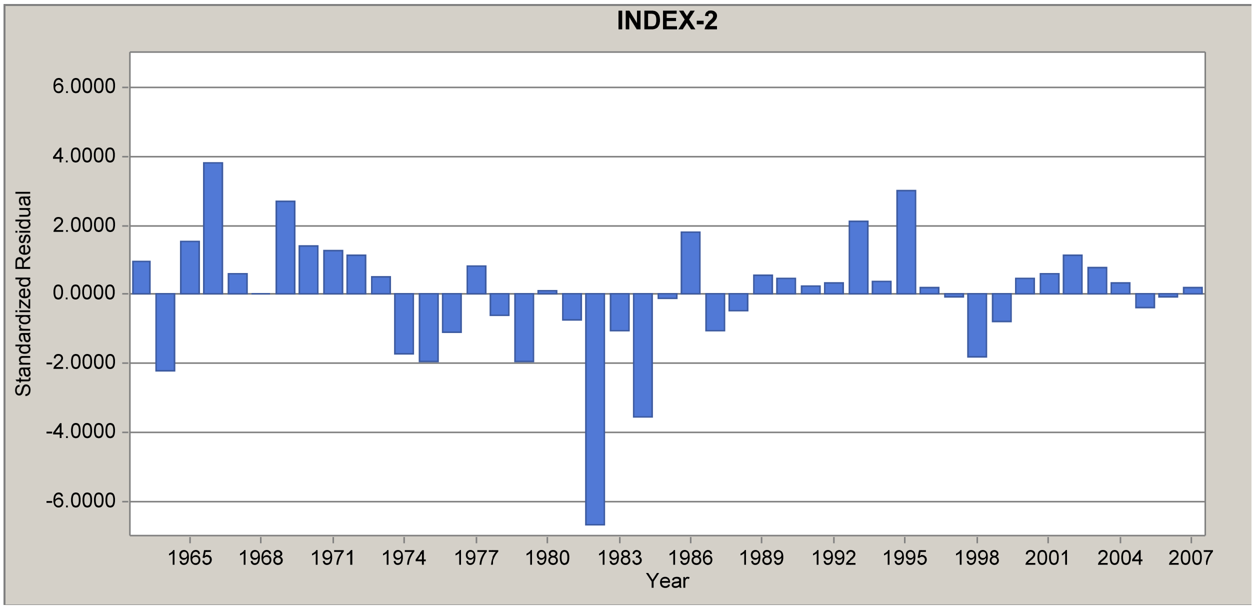


Figure B108. Residual pattern from the autumn survey GARM III final meeting ASAP run.

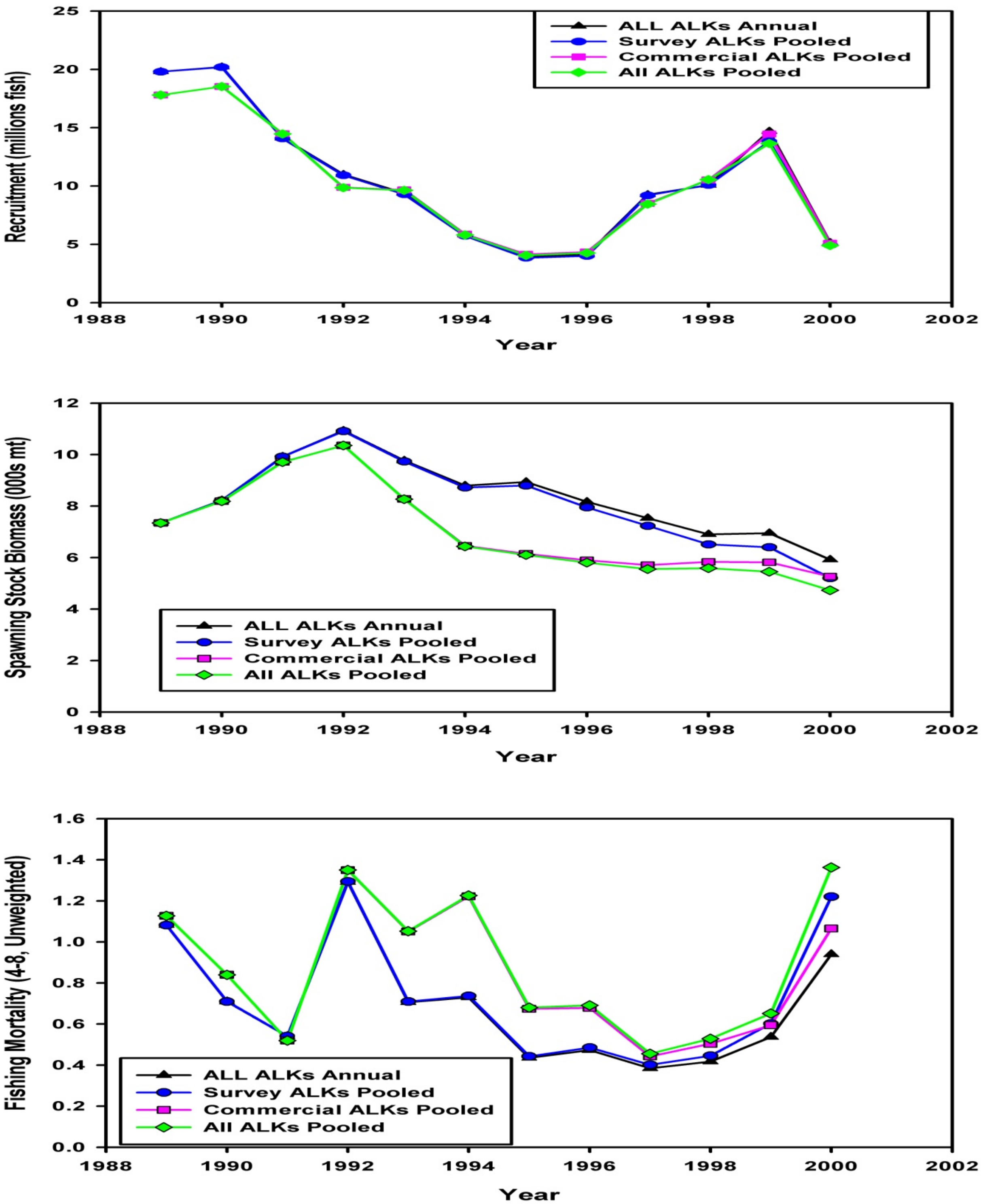


Figure B109. Results from the VPA model formulations for examining the use of pooled ALKs. The top panel is recruitment in millions of fish, the middle panel is spawning stock biomass in 000s mt , and the bottom panel is fully recruited fishing mortality (Ages 5-8).

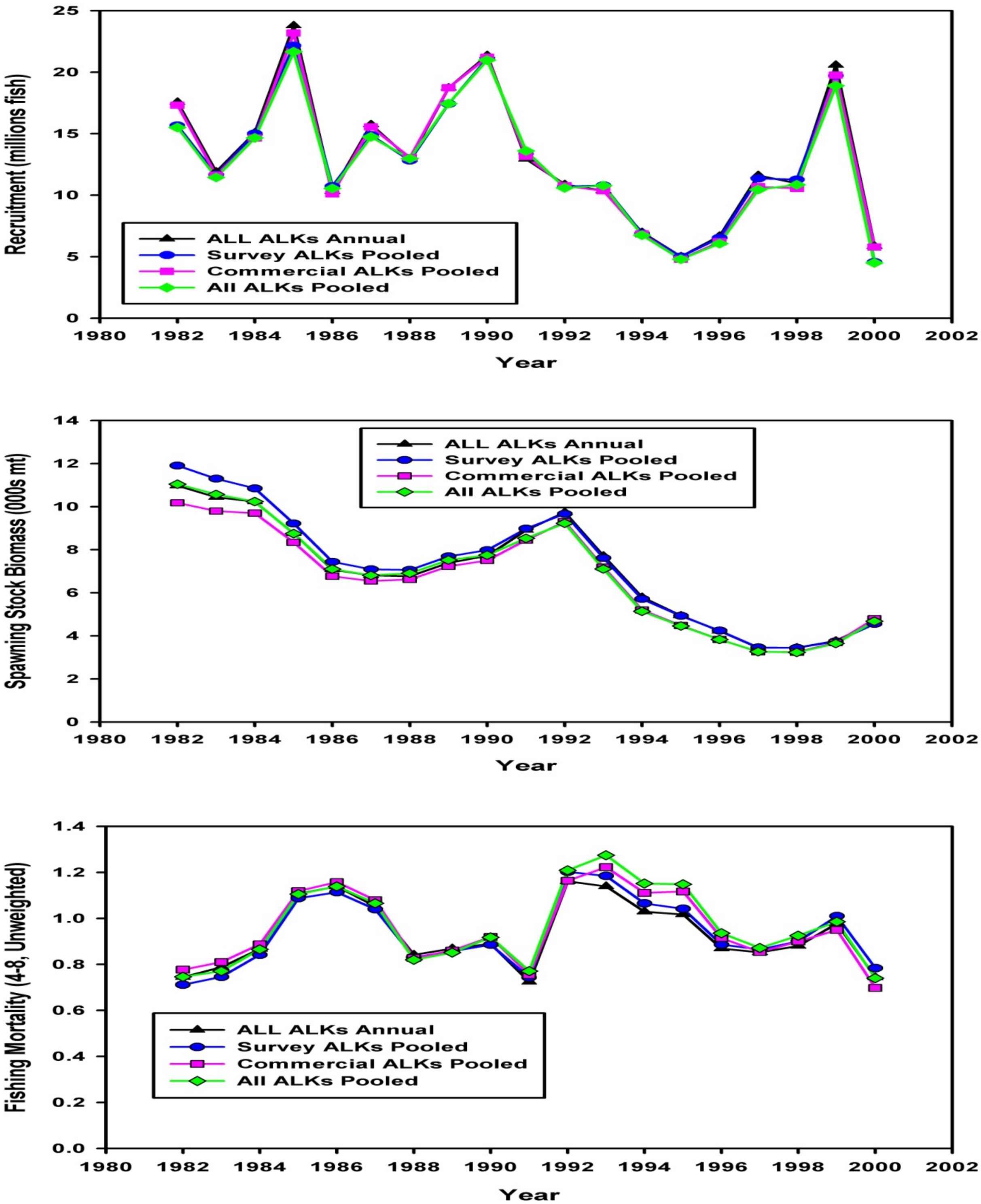


Figure B110. Results from the ASAP model formulations used to examine the use of pooled ALKs. The top panel is recruitment in millions of fish, the middle panel is spawning stock biomass in 000s mt , and the bottom panel is fully recruited fishing mortality (Age 5).

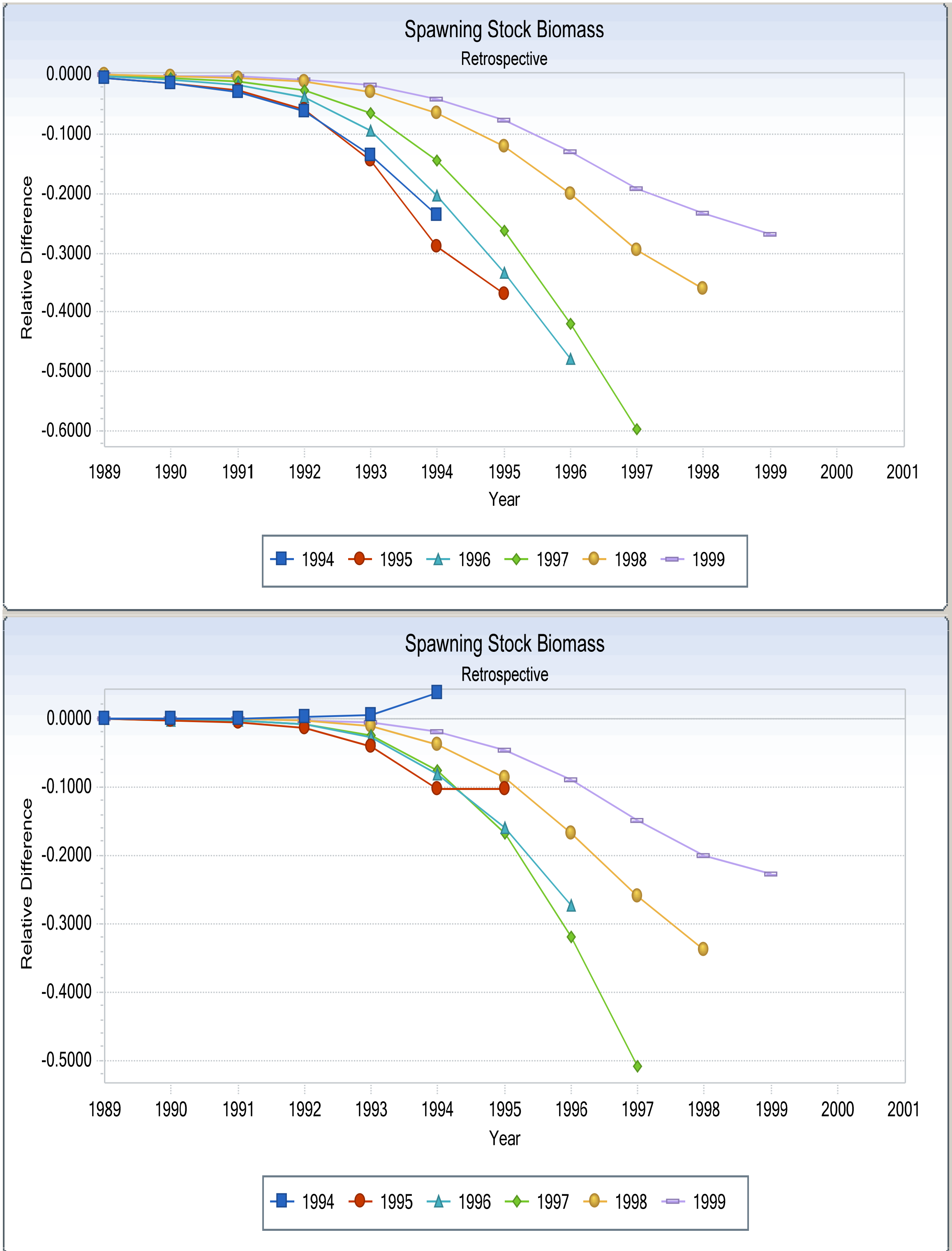


Figure B111. Retrospective results of SSB from the VPA formulations, all ALKs un-pooled (top panel) and commercial only pooled (bottom panel).

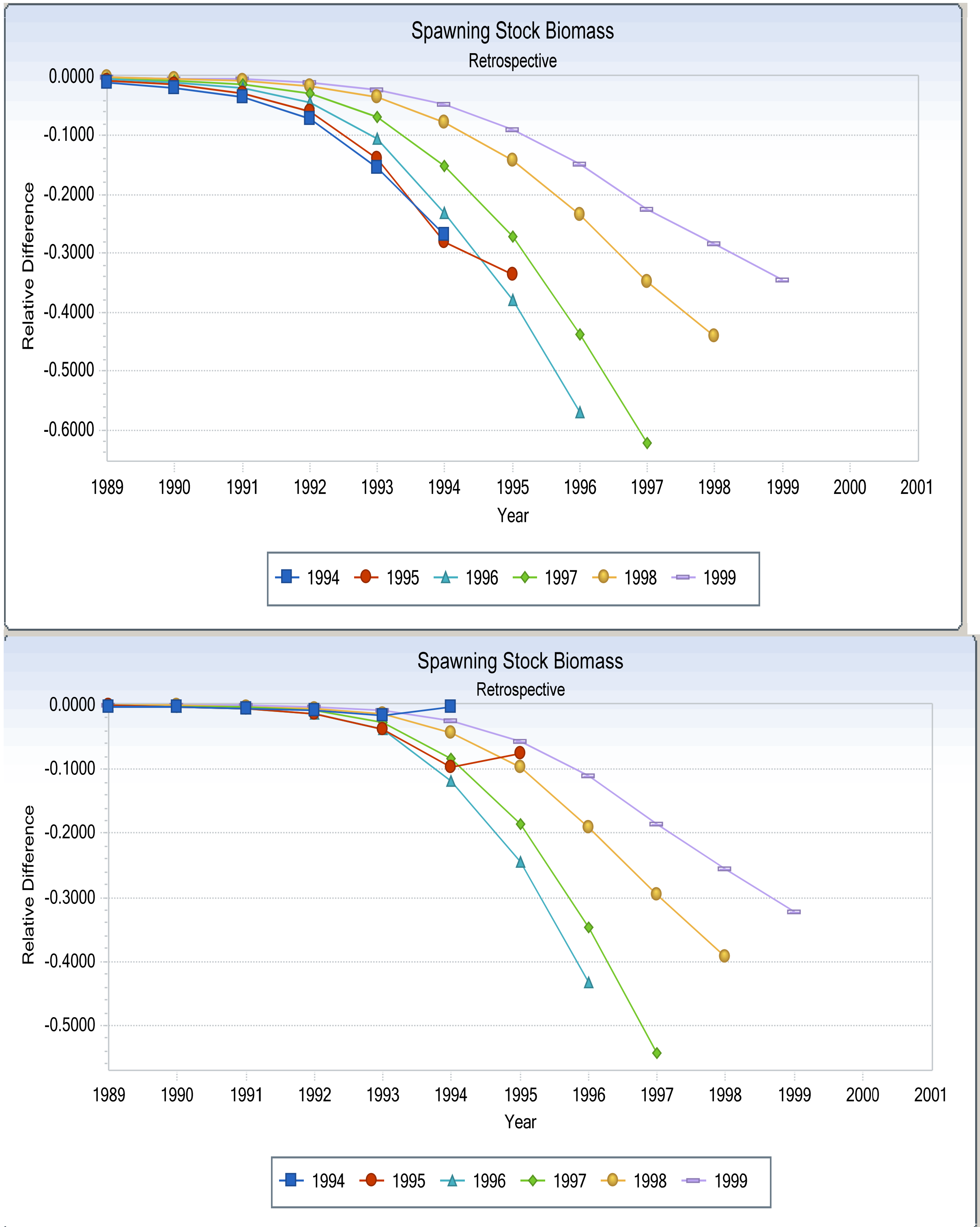


Figure B112. Retrospective results of SSB from the VPA formulations, survey ALKs pooled (top panel) and all ALKs pooled (bottom panel).

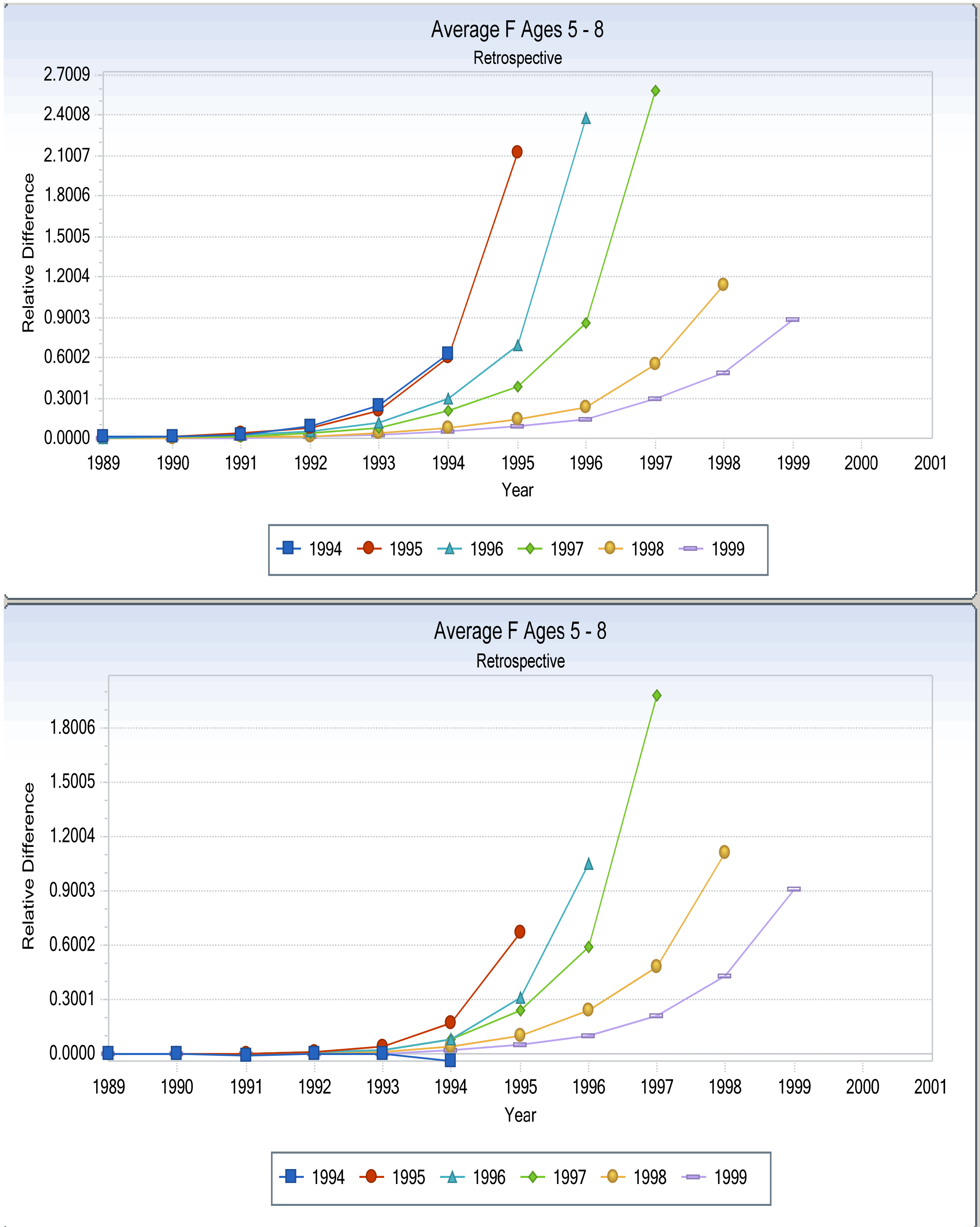


Figure B113. Retrospective results of fishing mortality (Ages 5-8) from the VPA formulations, all ALKs un-pooled (top panel) and commercial only pooled (bottom panel).

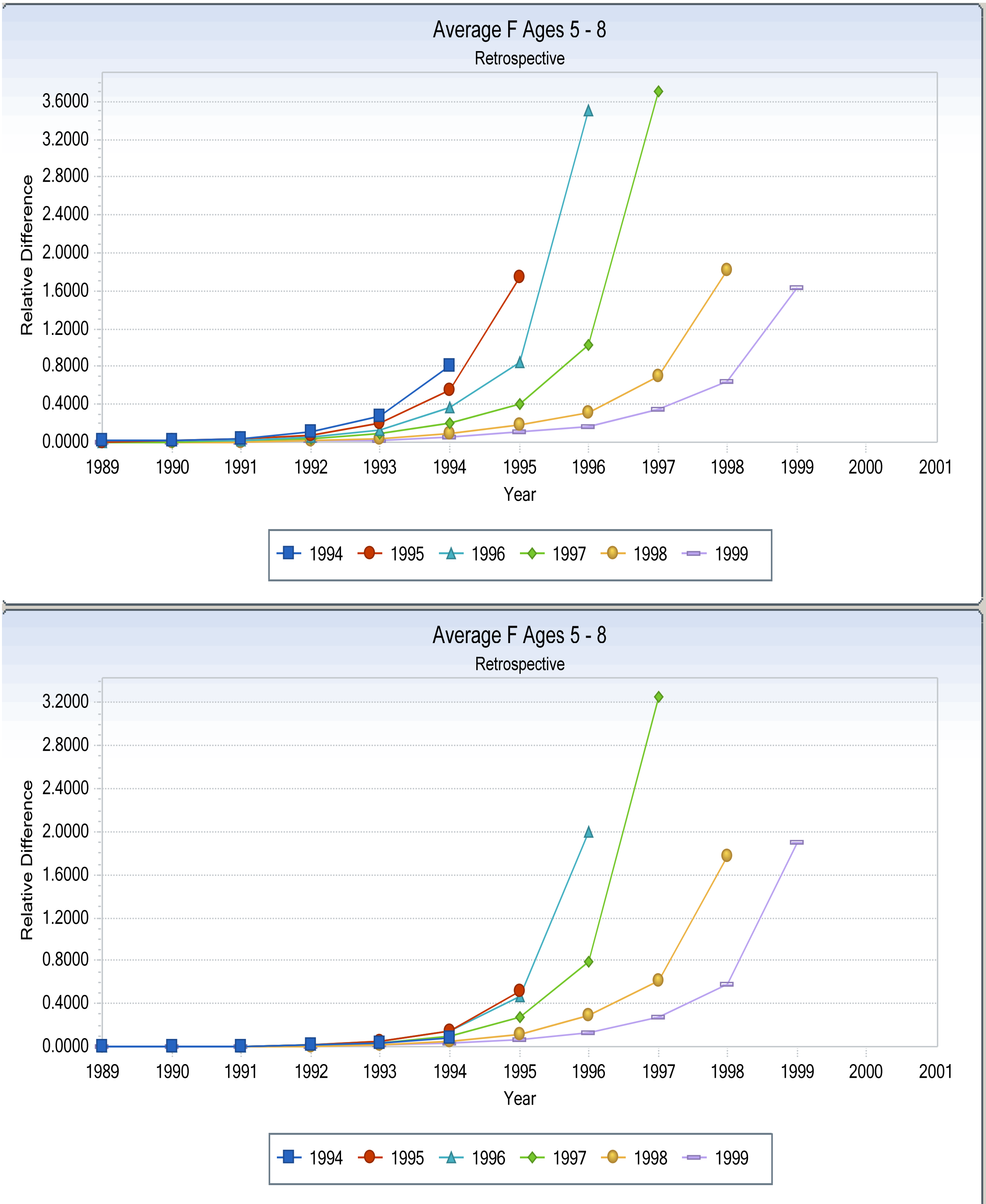
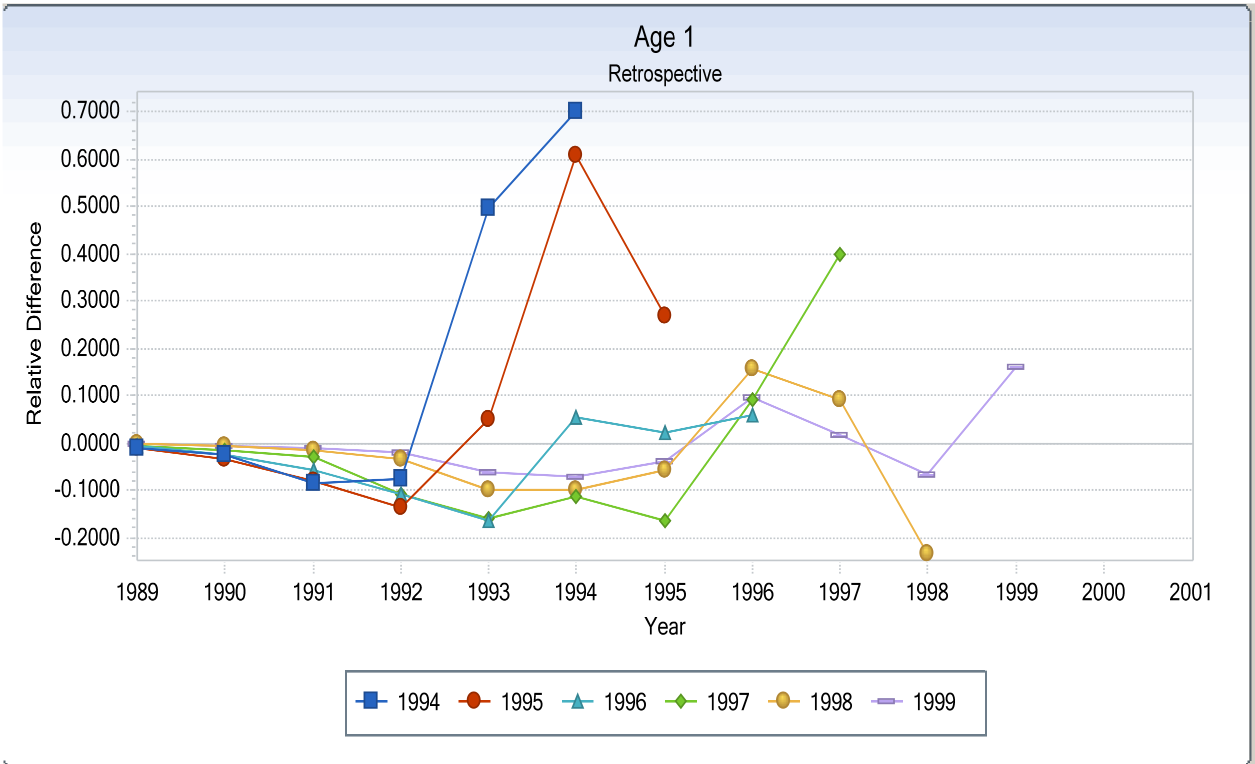


Figure B114. Retrospective results of fishing mortality (Ages 5-8) from the VPA formulations, survey ALKs pooled (top panel) and all ALKs pooled (bottom panel).



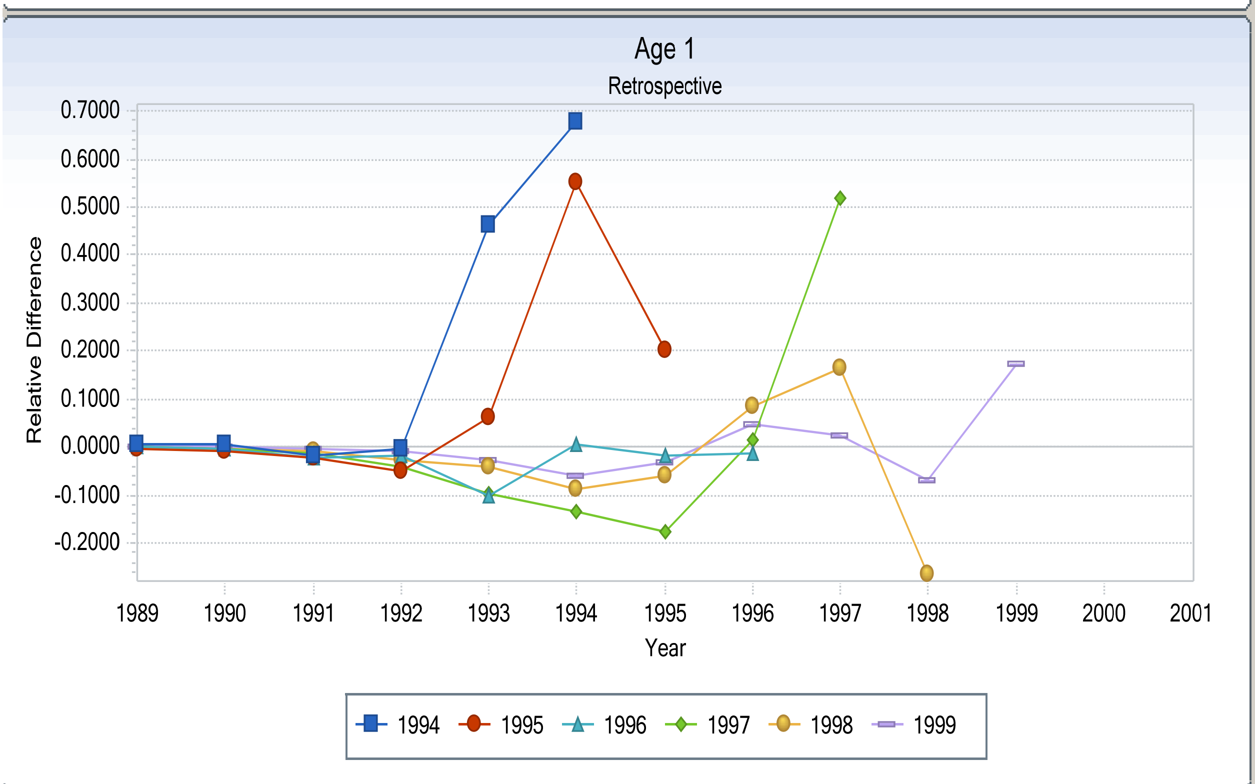
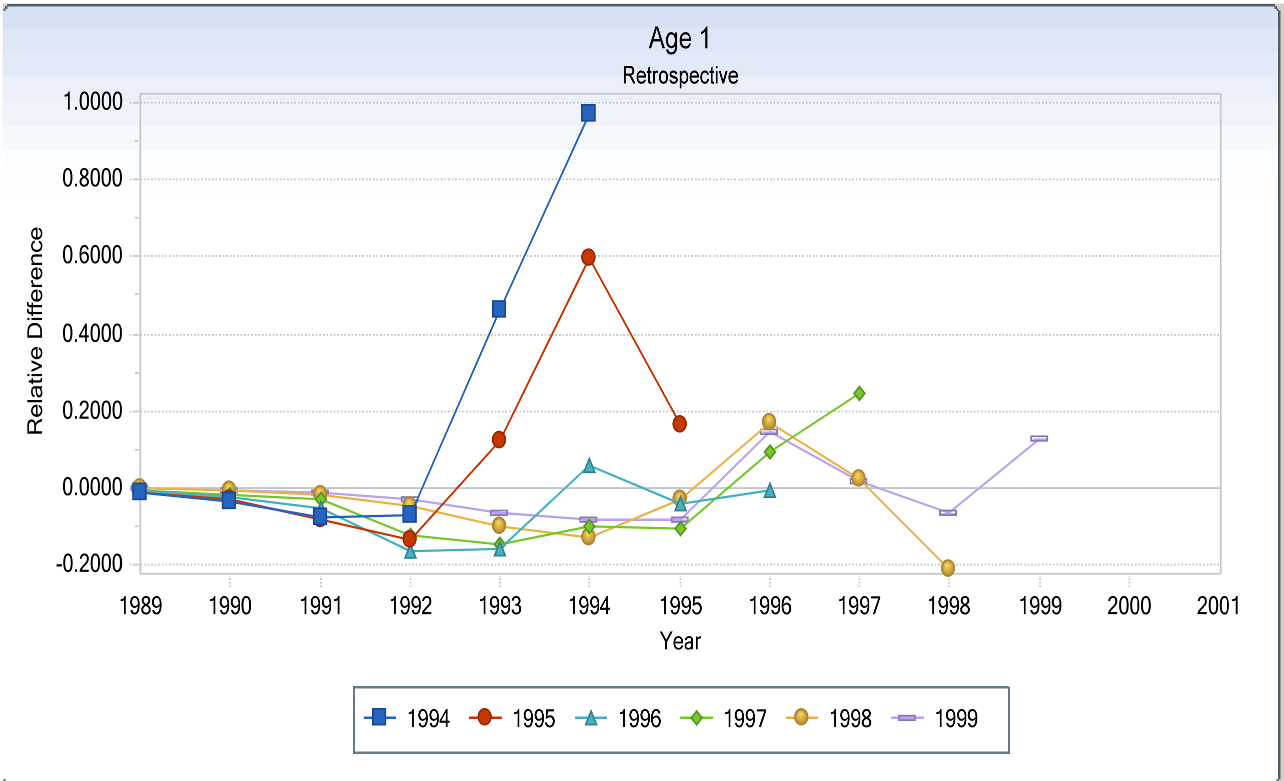


Figure B115. Retrospective results of recruitment from the VPA formulations, all ALKs un-pooled (top panel) and commercial only pooled (bottom panel).



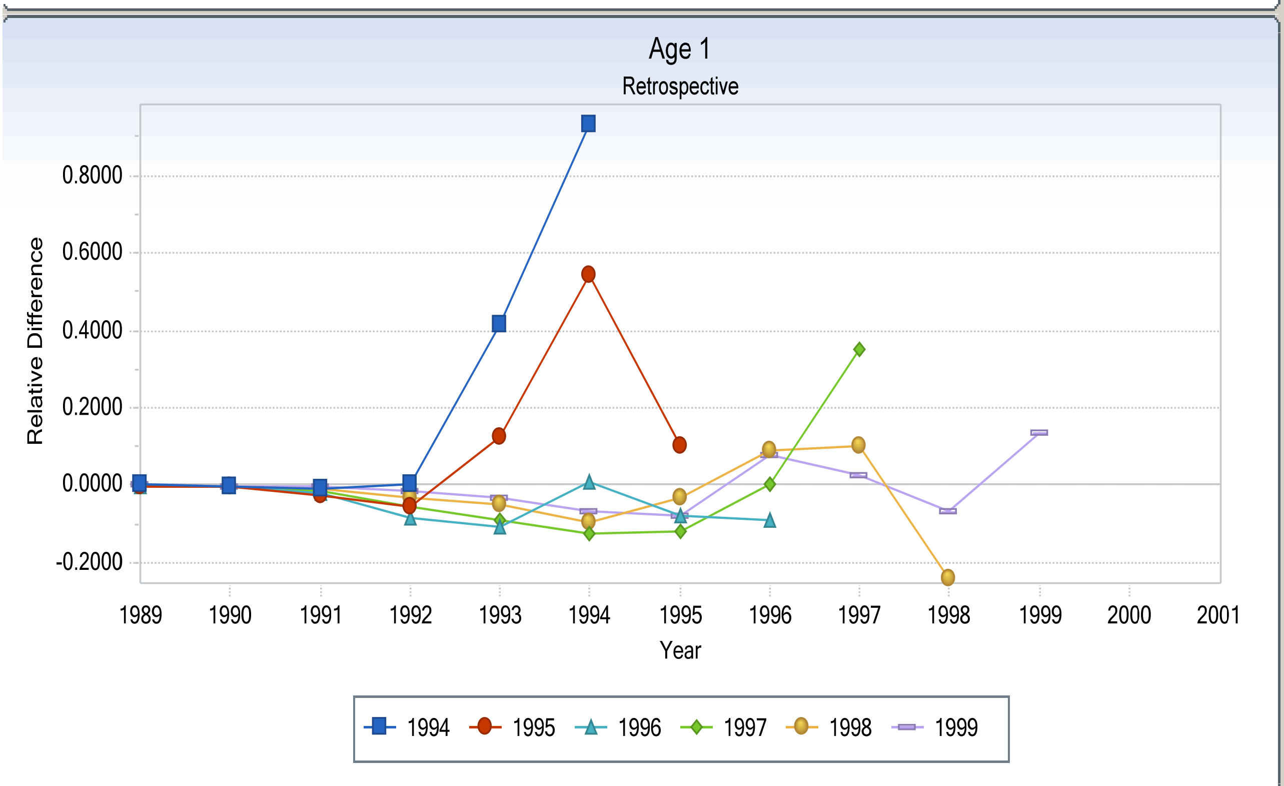


Figure B116. Retrospective results of recruitment from the VPA formulations, survey ALKs pooled (top panel) and all ALKs pooled (bottom panel).

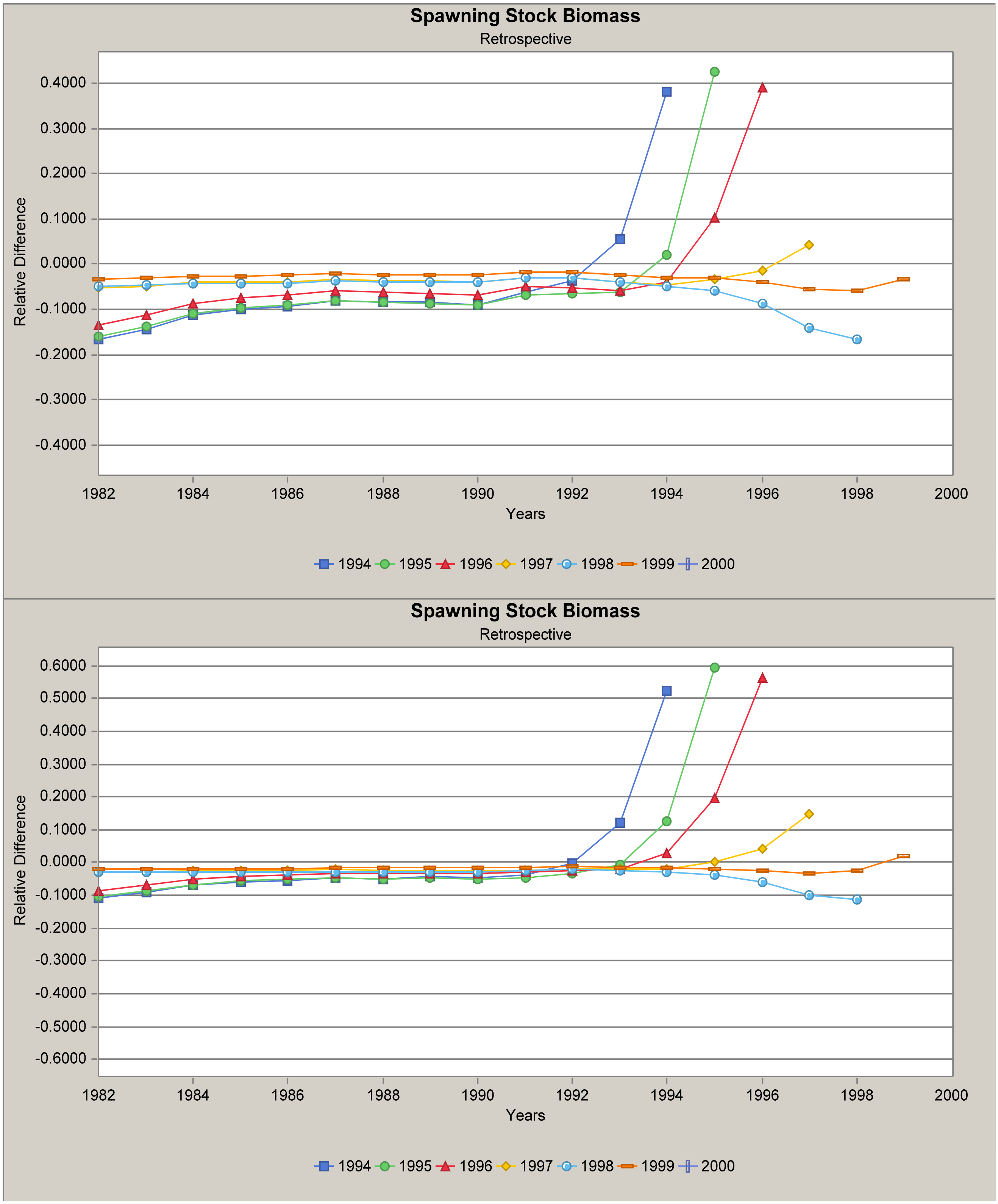


Figure B117. Retrospective results of SSB from the ASAP formulations, all ALKs un-pooled (top panel) and commercial only pooled (bottom panel).

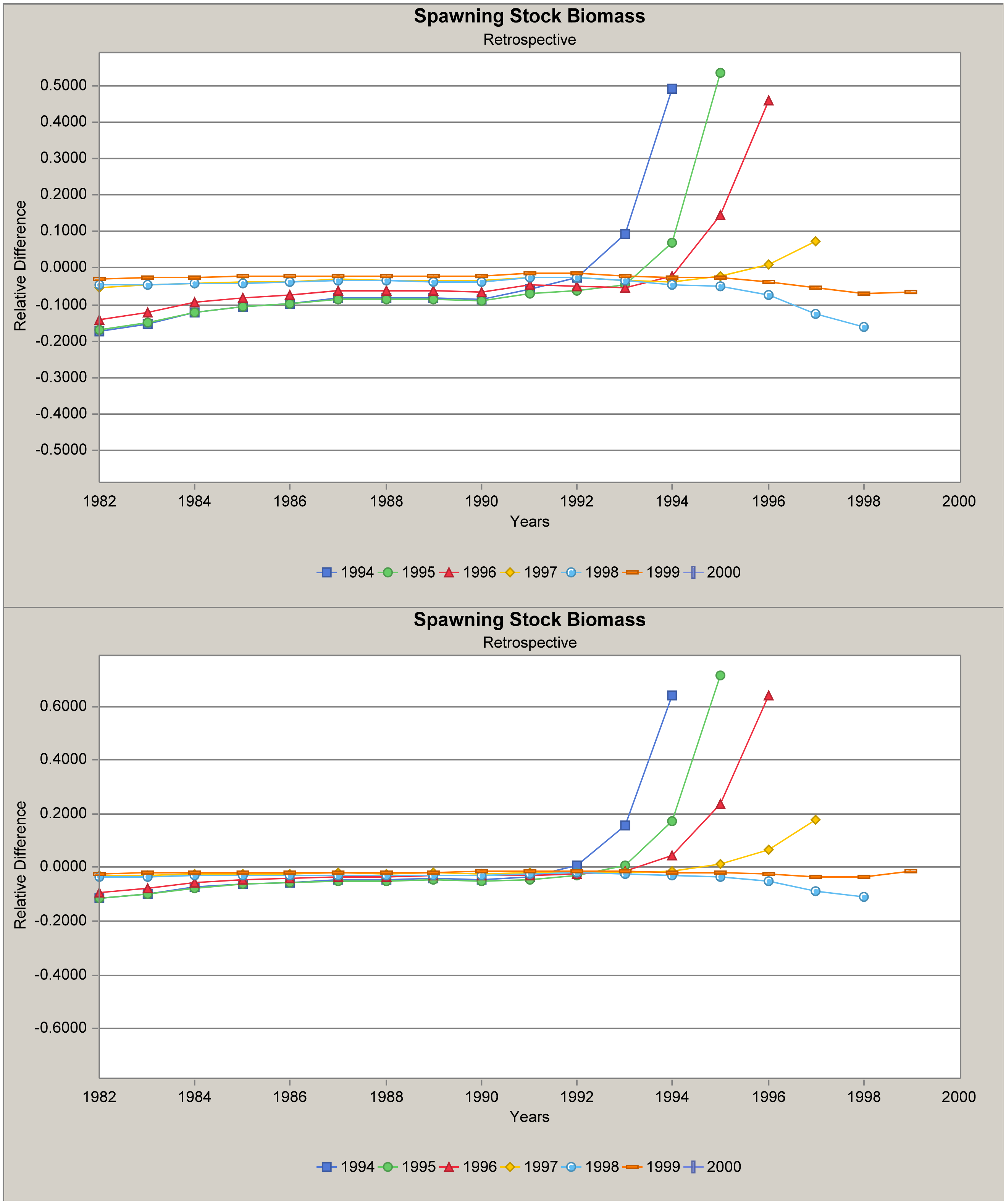
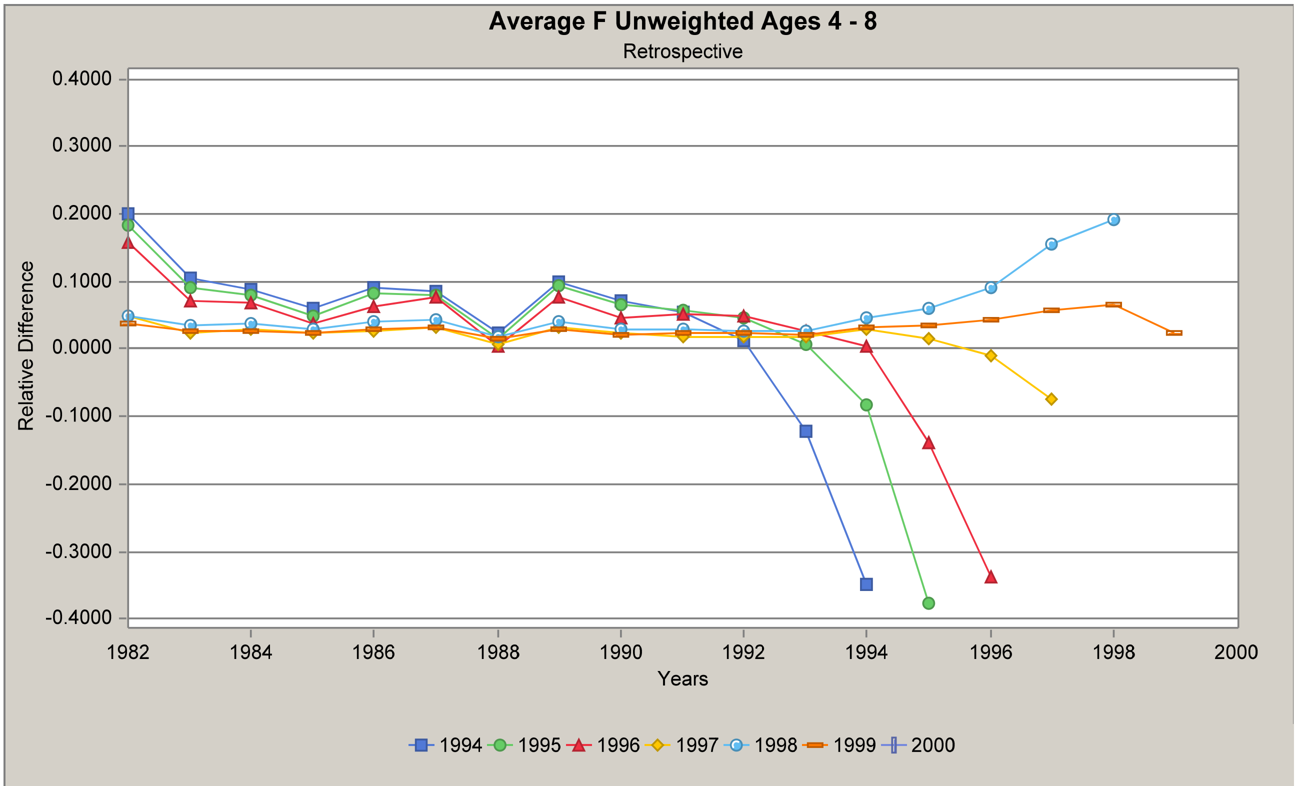


Figure B118. Retrospective results of SSB from the ASAP formulations, survey ALKs pooled (top panel) and all ALKs pooled (bottom panel).



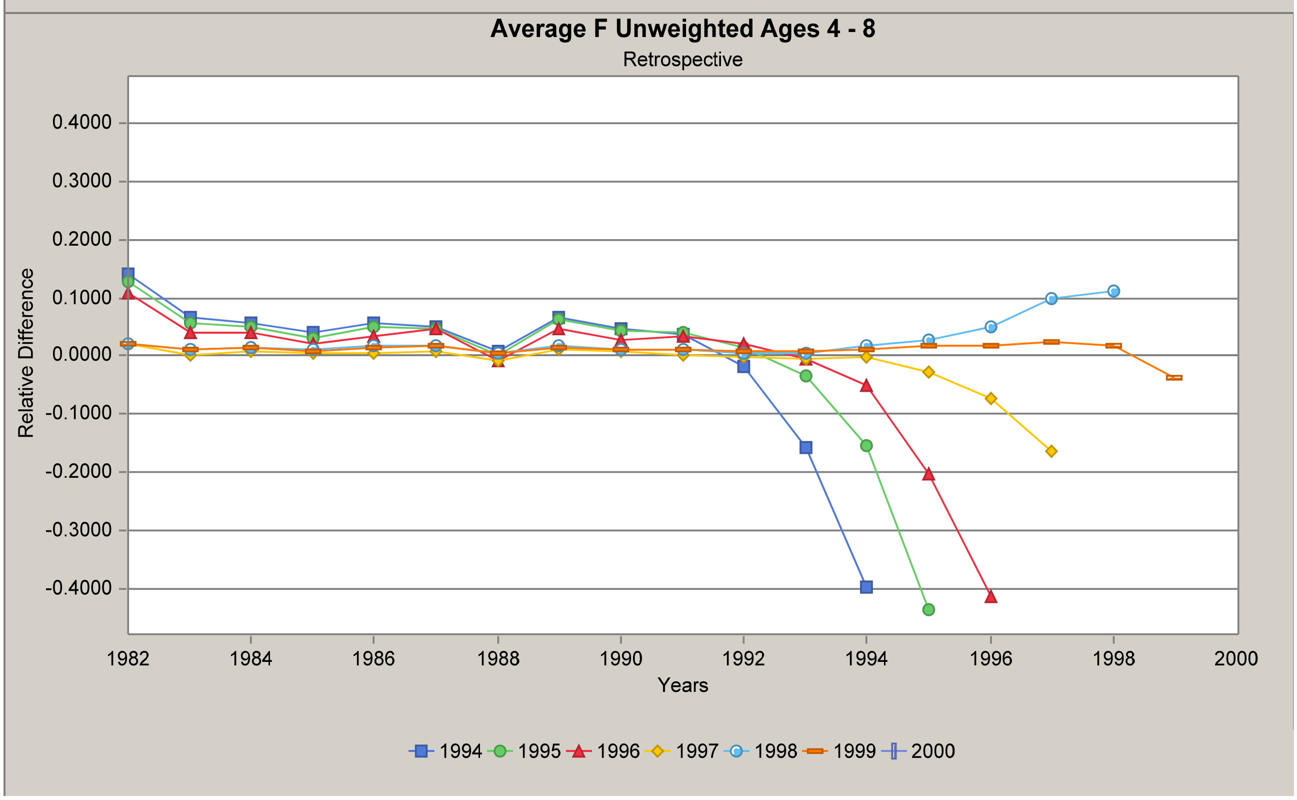


Figure B119. Retrospective results of fishing mortality (5-8) from the ASAP formulations, all ALKs un-pooled (top panel) and commercial only pooled (bottom panel).

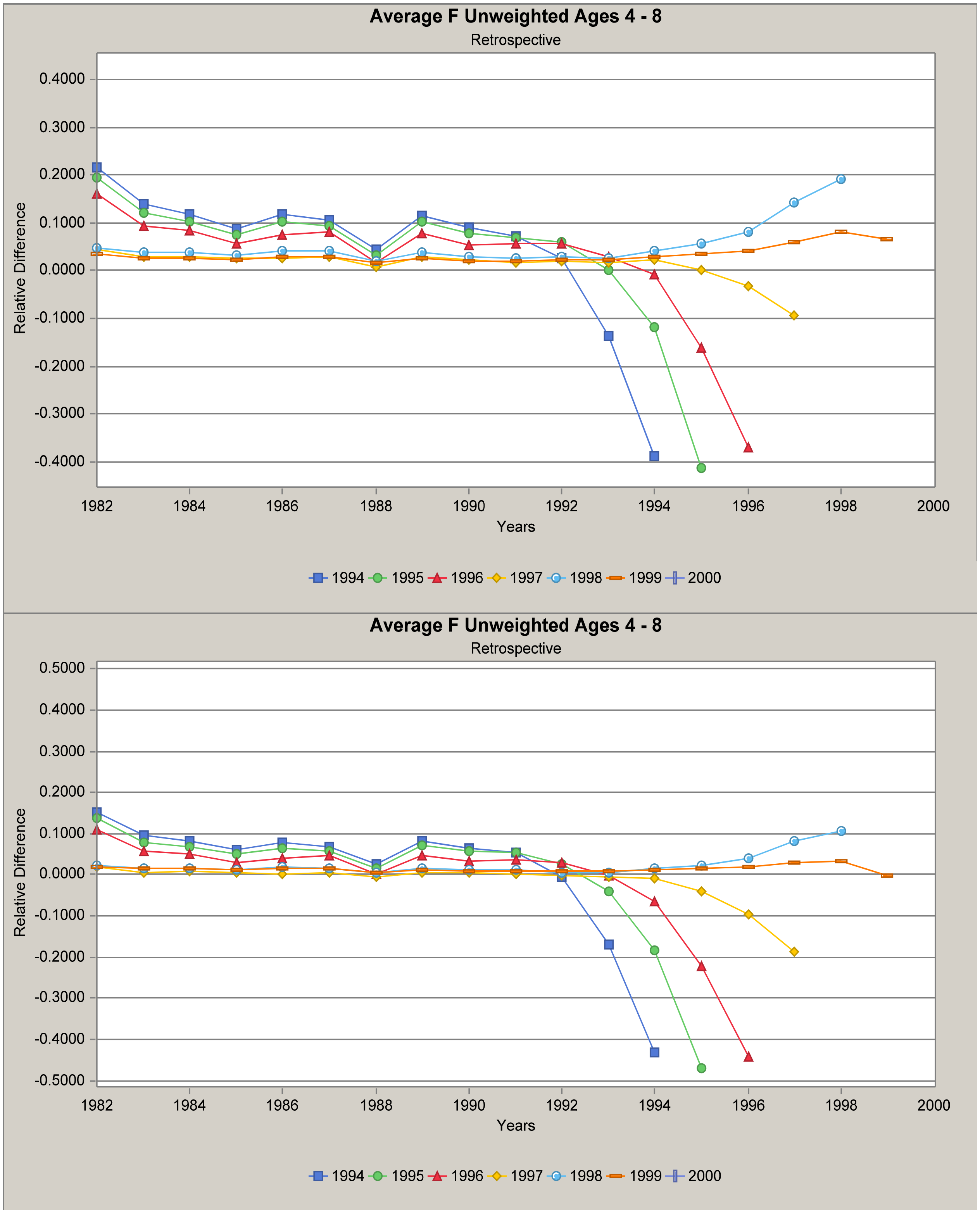
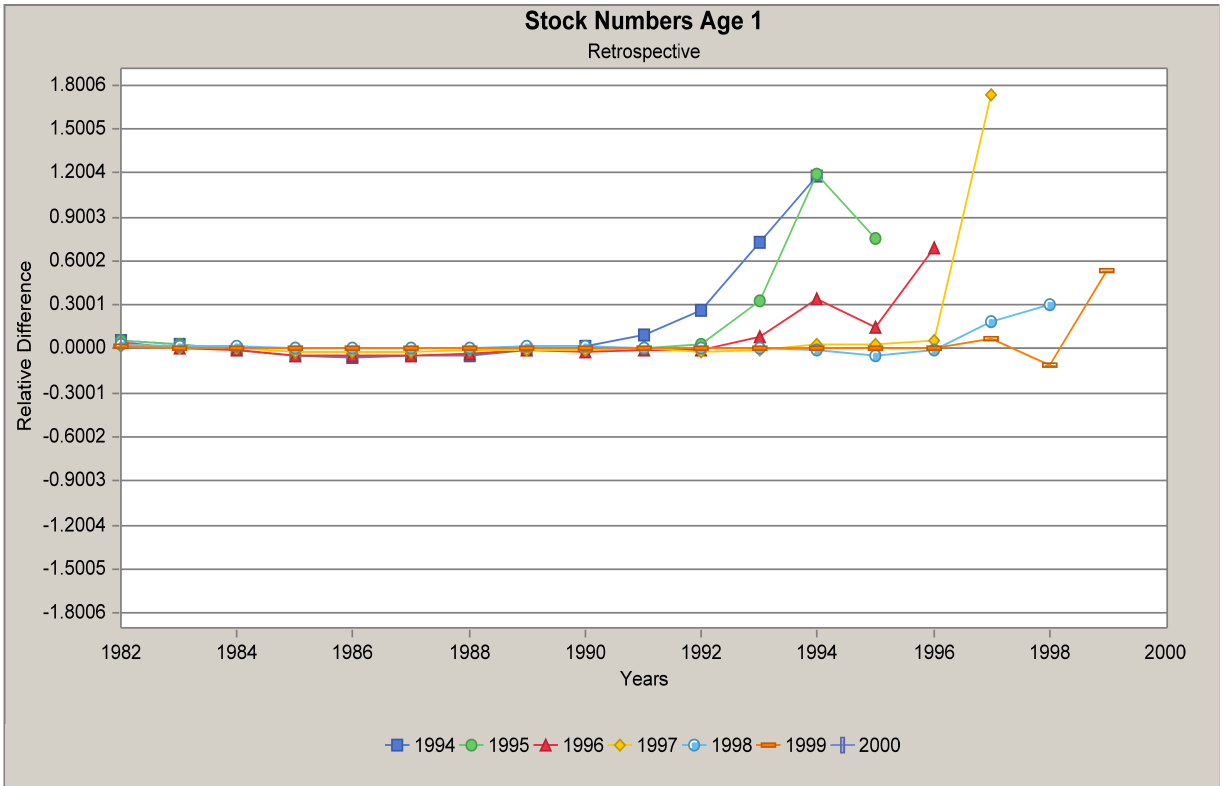


Figure B120. Retrospective results of fishing mortality (5-8) from the ASAP formulations, survey ALKs pooled (top panel) and all ALKs pooled (bottom panel).



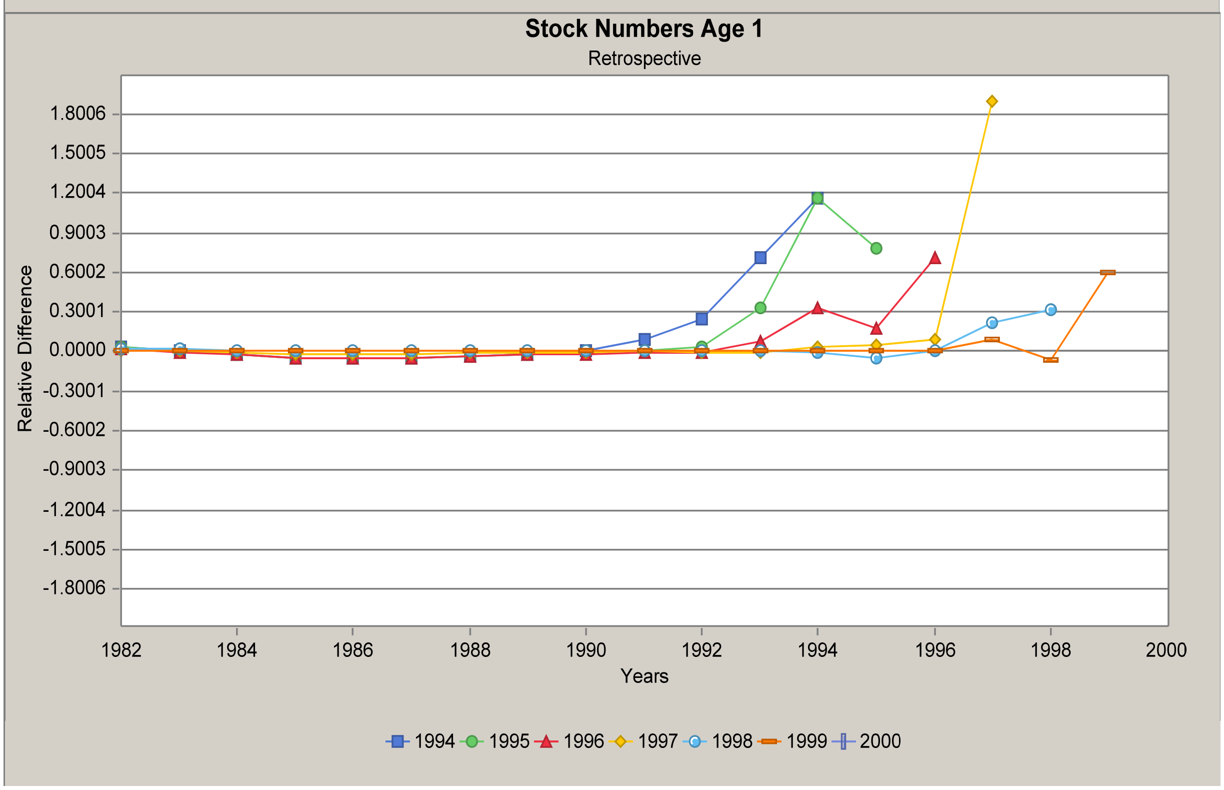
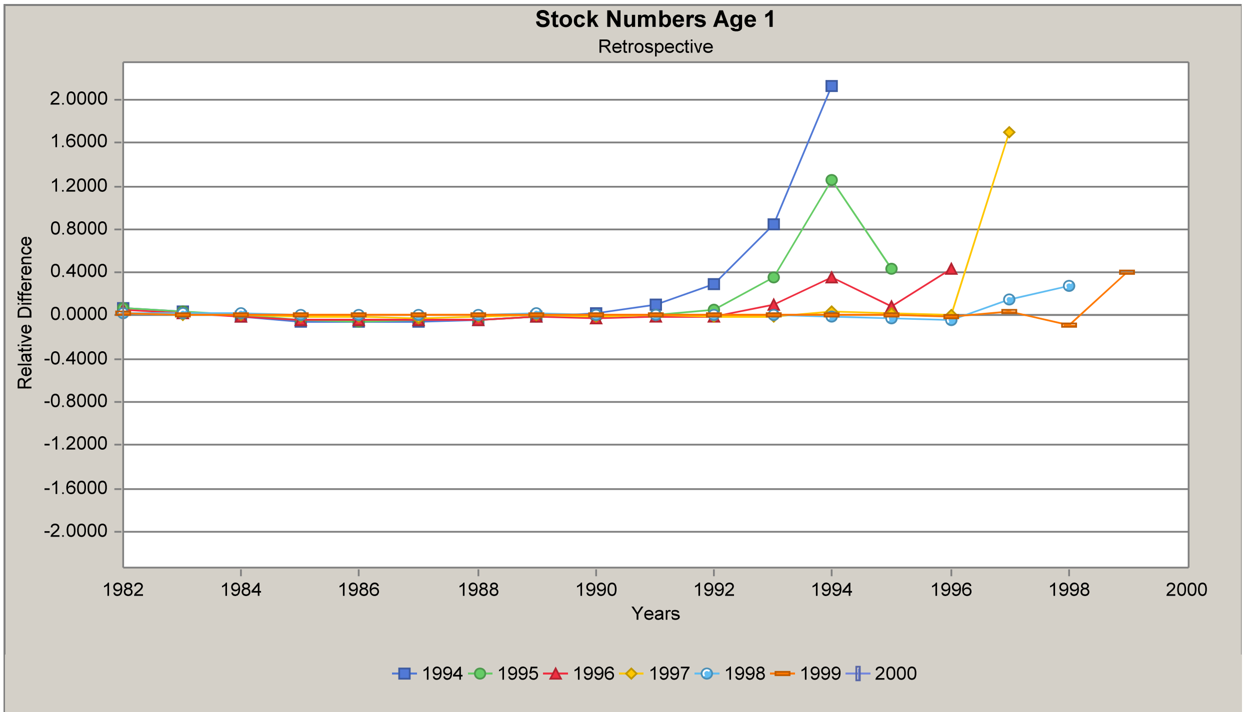


Figure B121. Retrospective results of recruitment from the ASAP formulations, all ALKs un-pooled (top panel) and commercial only pooled (bottom panel).



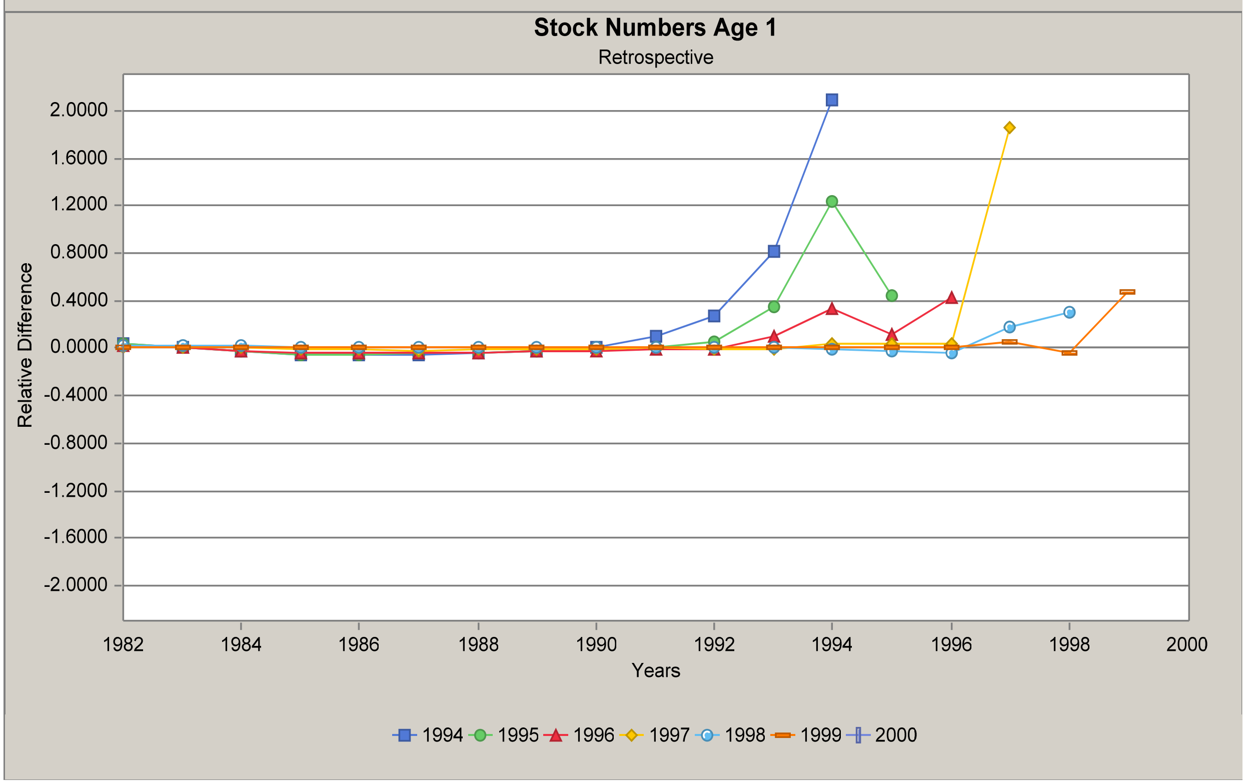


Figure B122. Retrospective results of recruitment from the ASAP formulations, survey ALKs pooled (top panel) and all ALKs pooled (bottom panel).

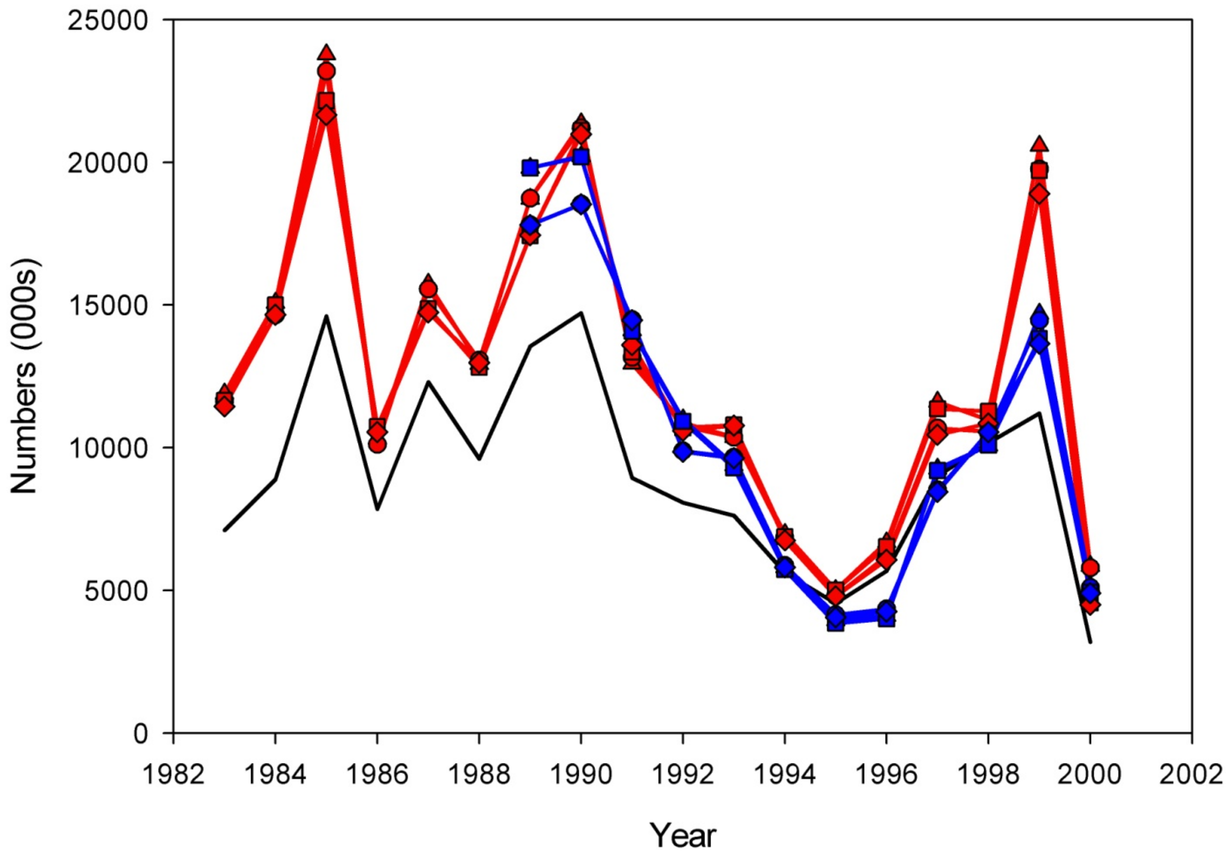


Figure B123. Comparison of recruitment estimates from the VPA (blue lines) and the ASAP (red lines) models for the pooled ALK analysis as well as the recruitment from the GARMIII model (black line).

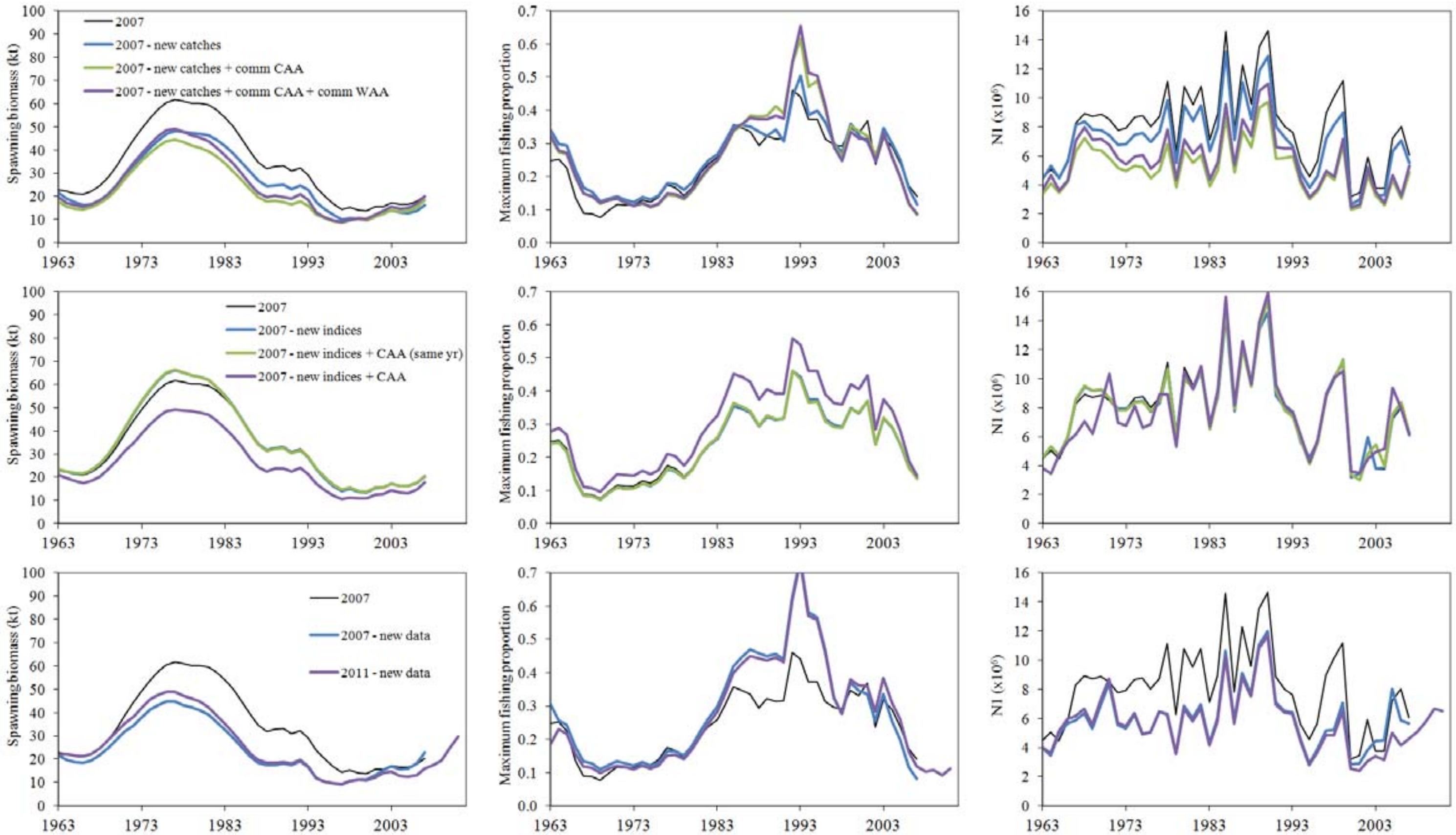


Figure. B124. Spawning biomass, maximum fishing proportion and recruitment trajectories from the bridge-building exercise using SCAA.

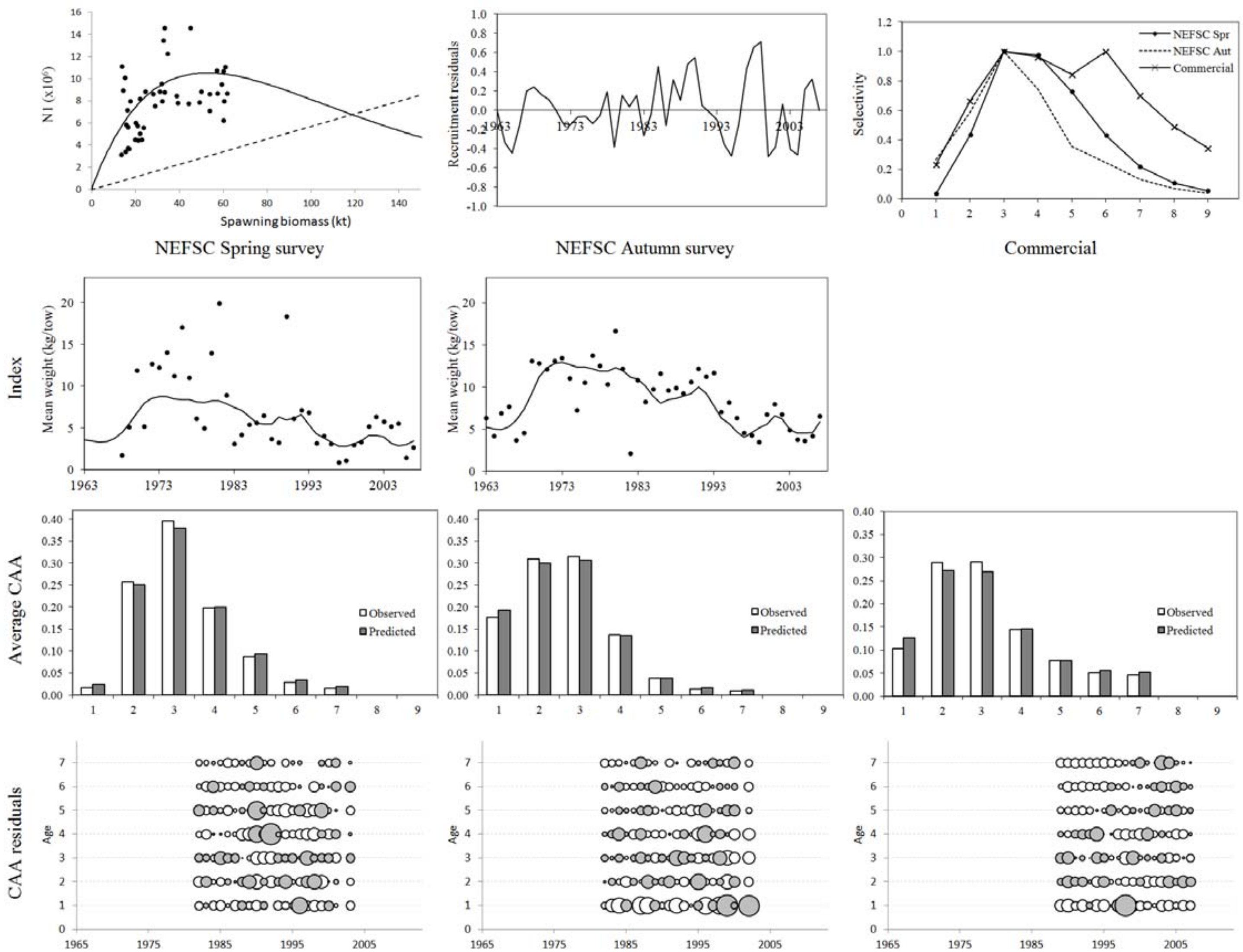


Figure B125. Results for the "2007" white hake assessment.

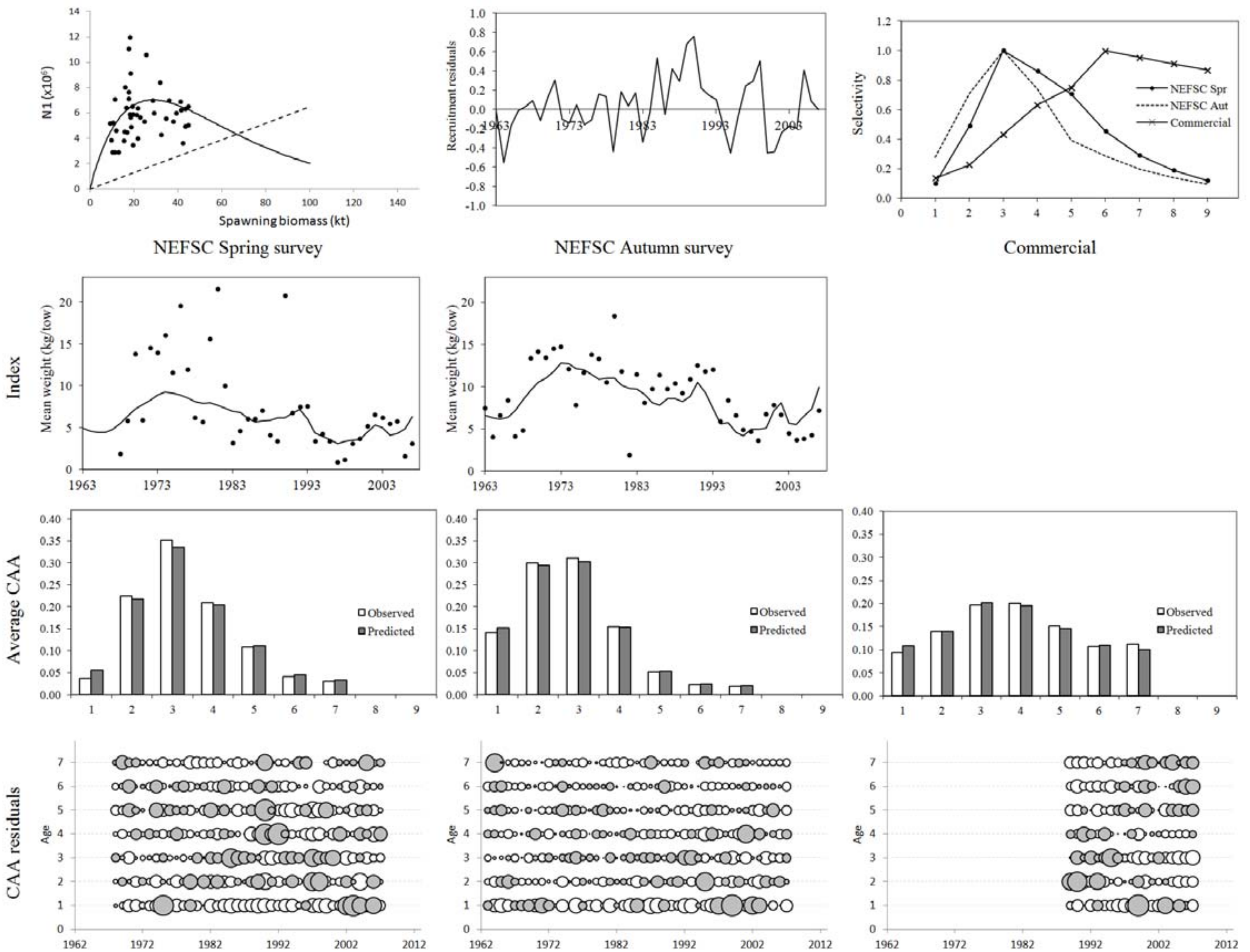


Figure B126: Results for the "2007 - new data" white hake assessment.

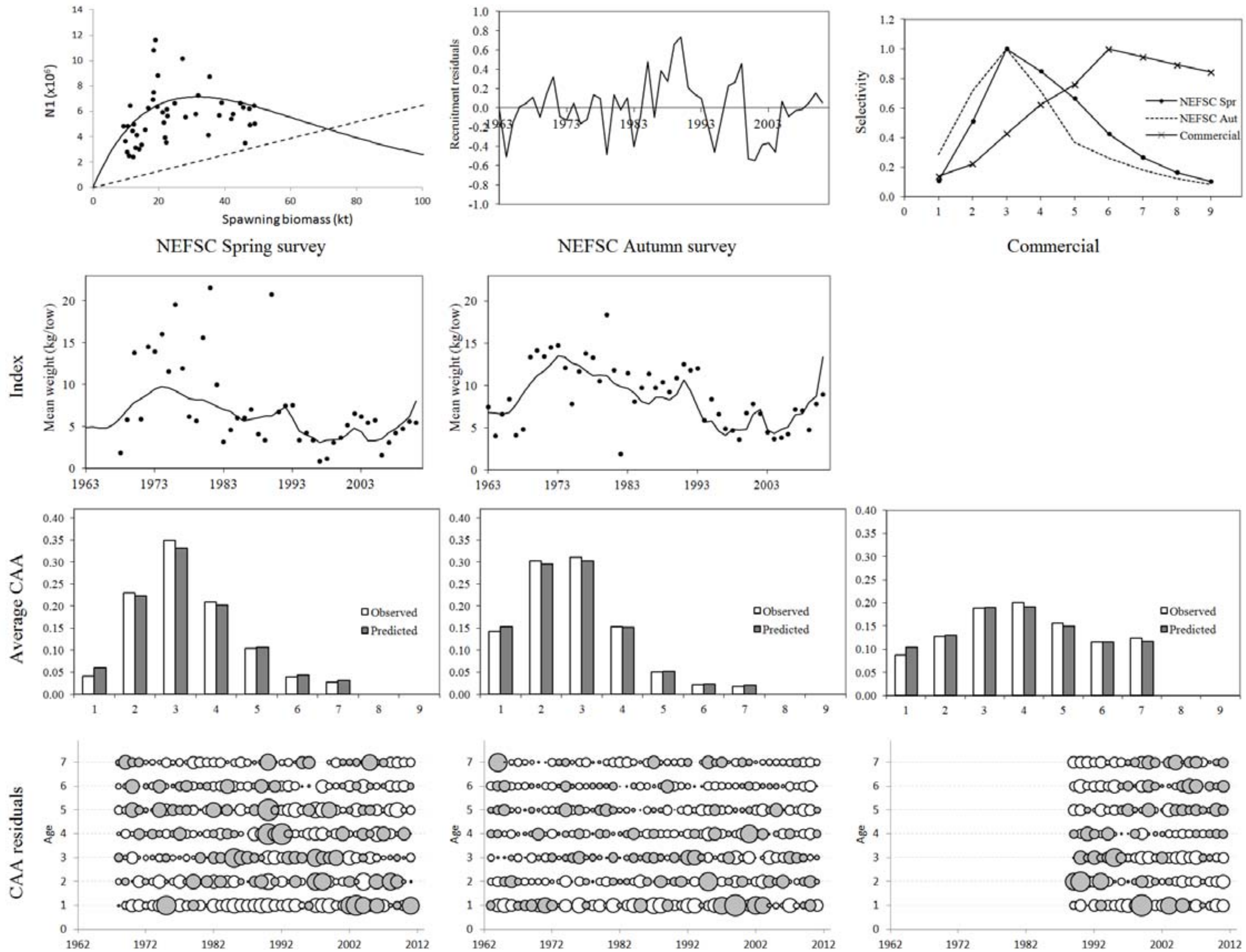


Figure B127. Results for the "2011 - new data" white hake assessment.

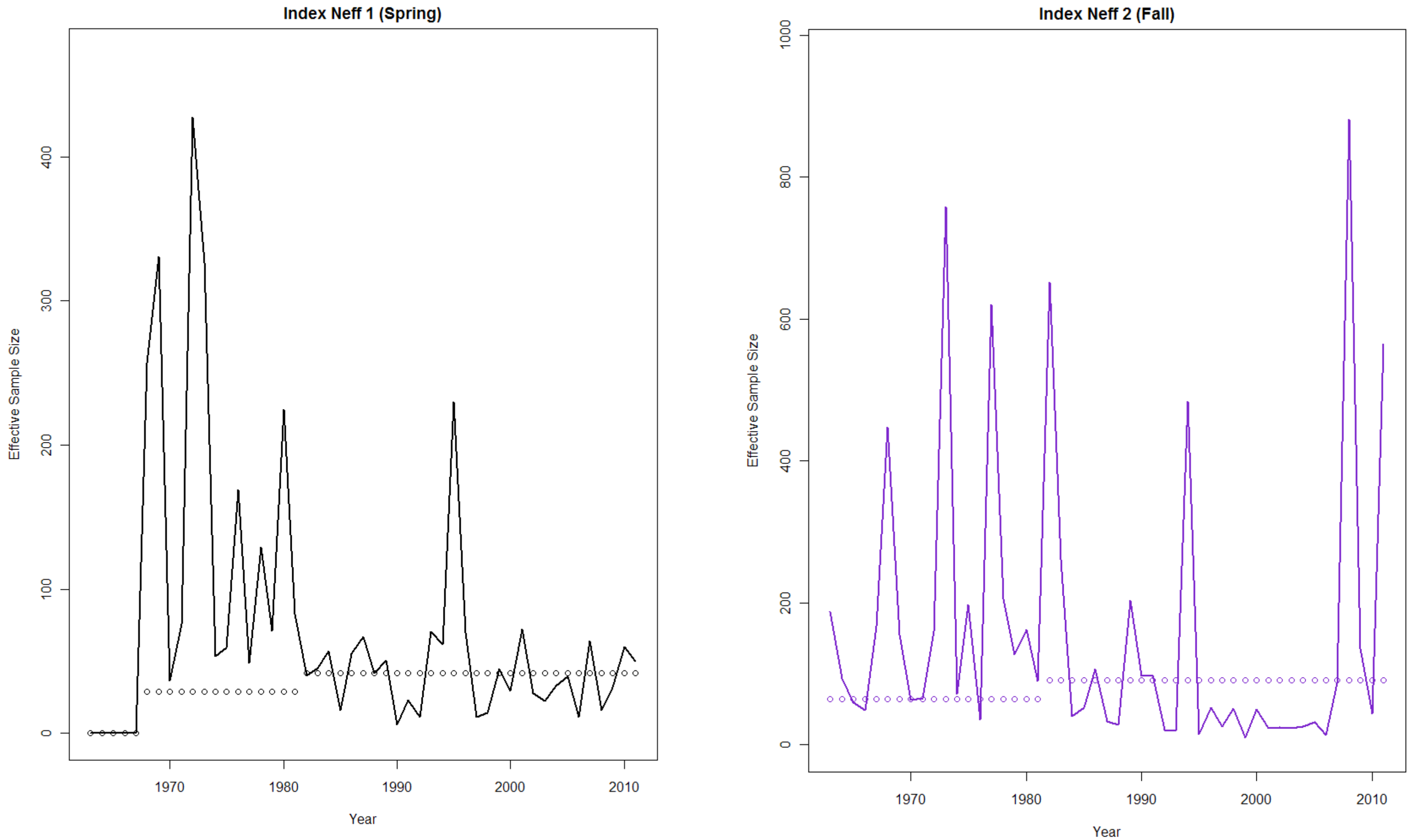


Figure B128. Effective sample sizes from the spring (left panel) and the autumn (right panel) surveys from the Base Model.

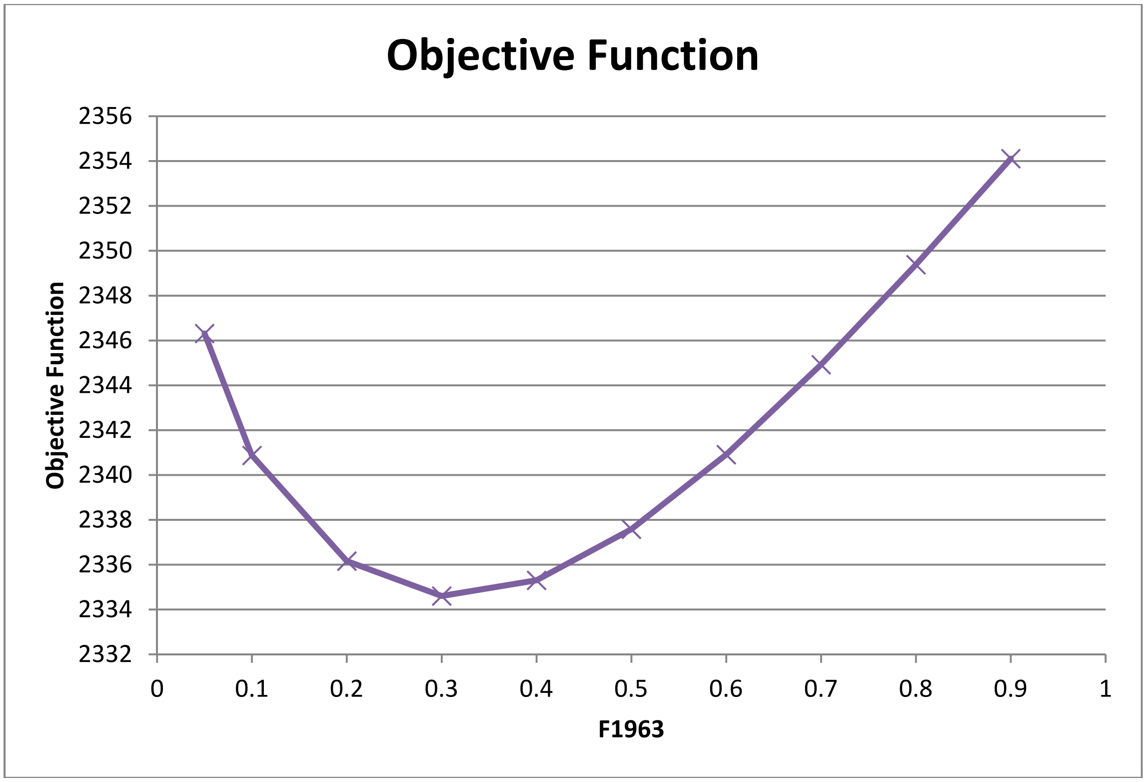


Figure B129. Profile of the objective function from ASAP runs in which the F1963 was fixed at different values.

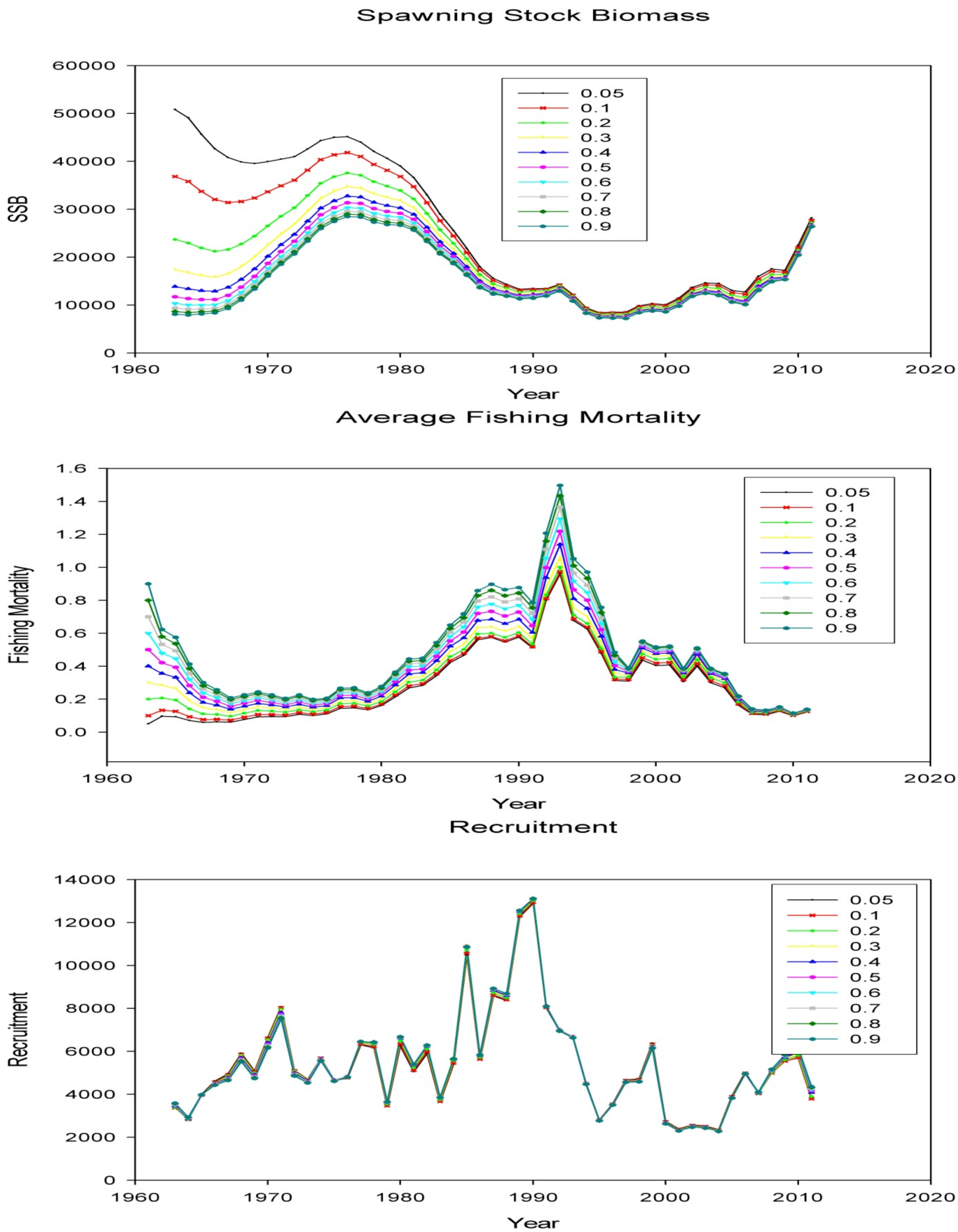


Figure B130. Comparison of the SSB (top panel), average fishing mortality (middle panel) and recruitment (bottom panel) under various values of F1963.

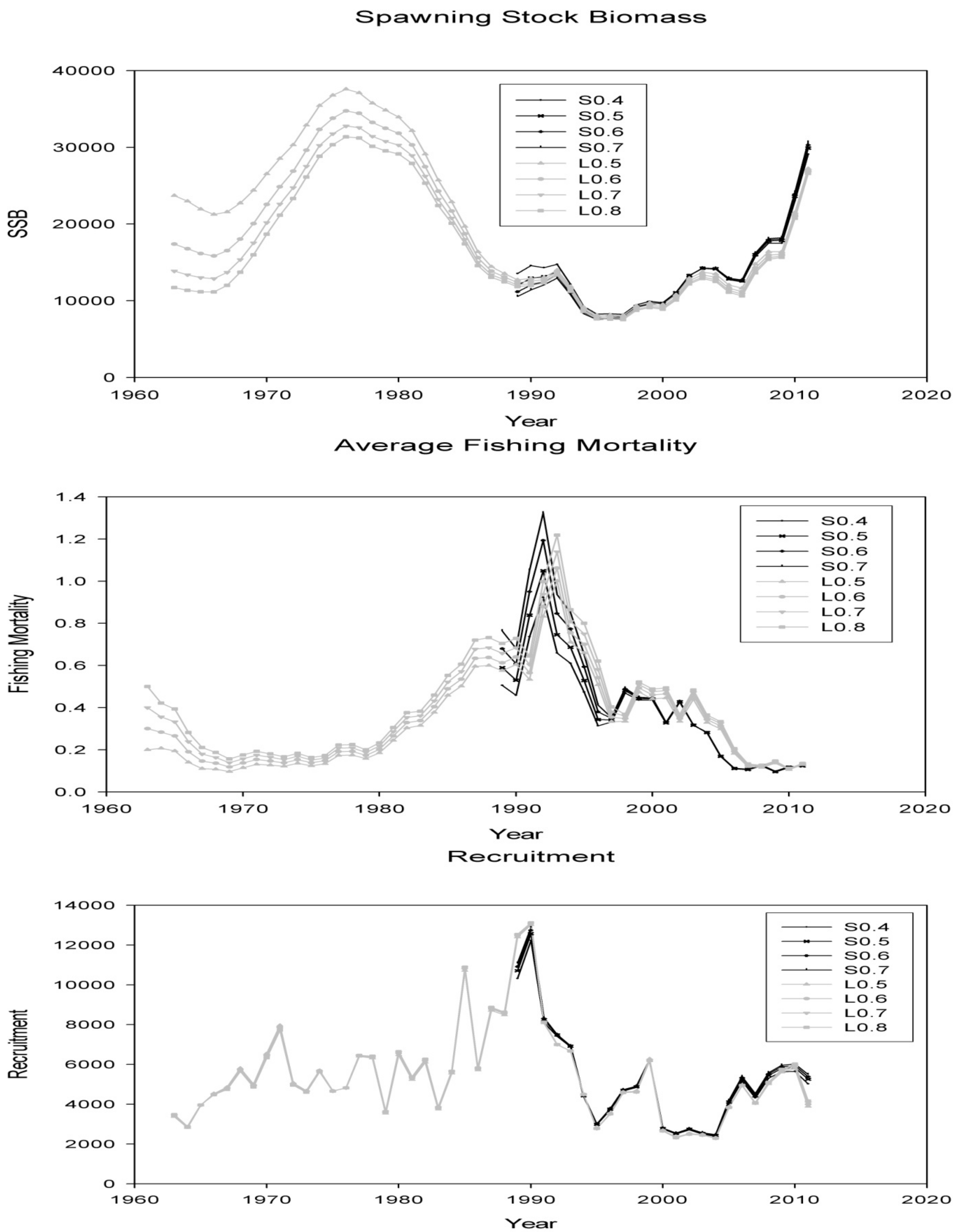


Figure B131. Comparison of the SSB (top panel), Average Fishing mortality (middle panel) and recruitment (bottom panel) under the most likely values of starting Fmult from the Base ASAP model and the 1989 ASAP model.

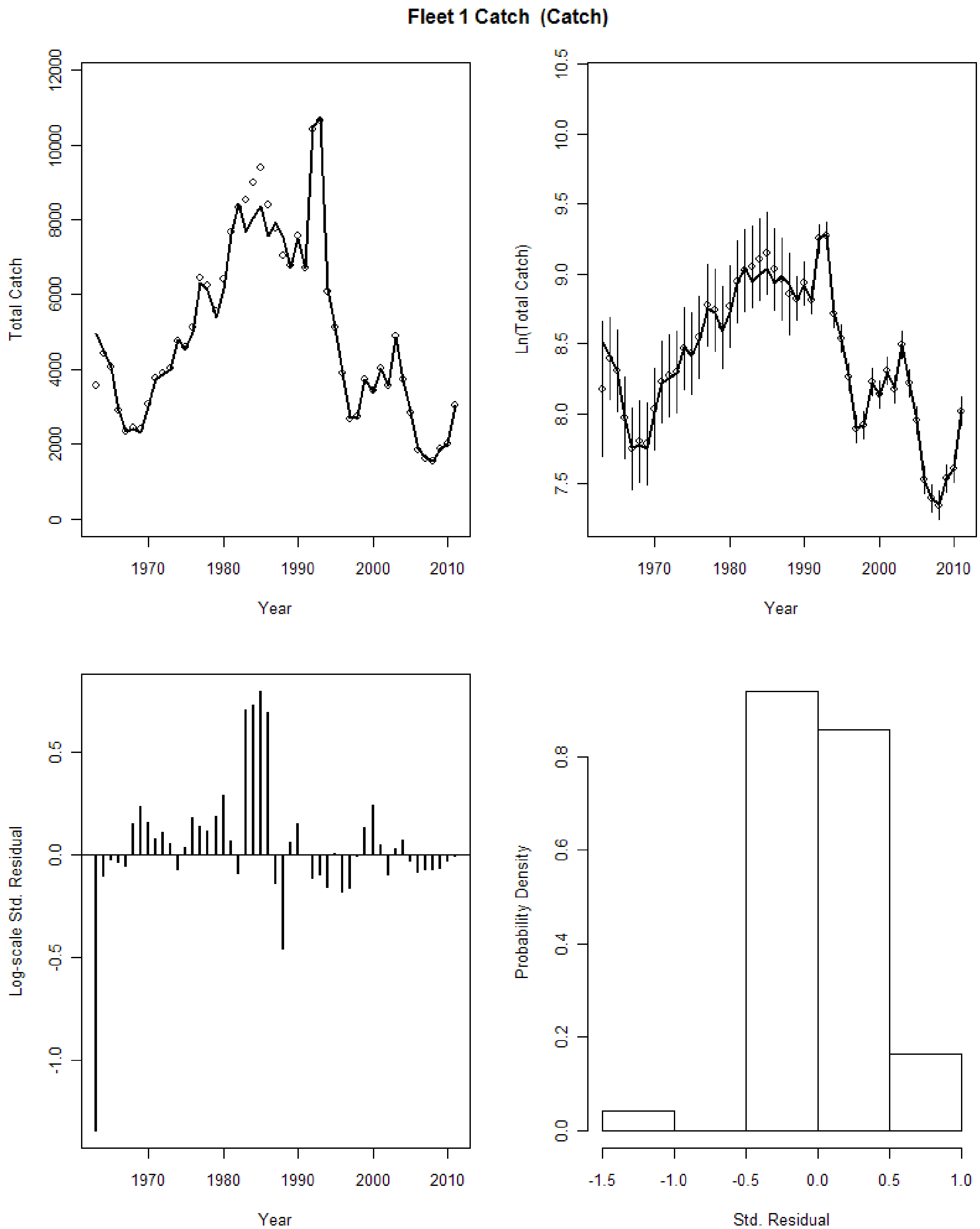


Figure B132. Fits to the catch data from the Base ASAP model.

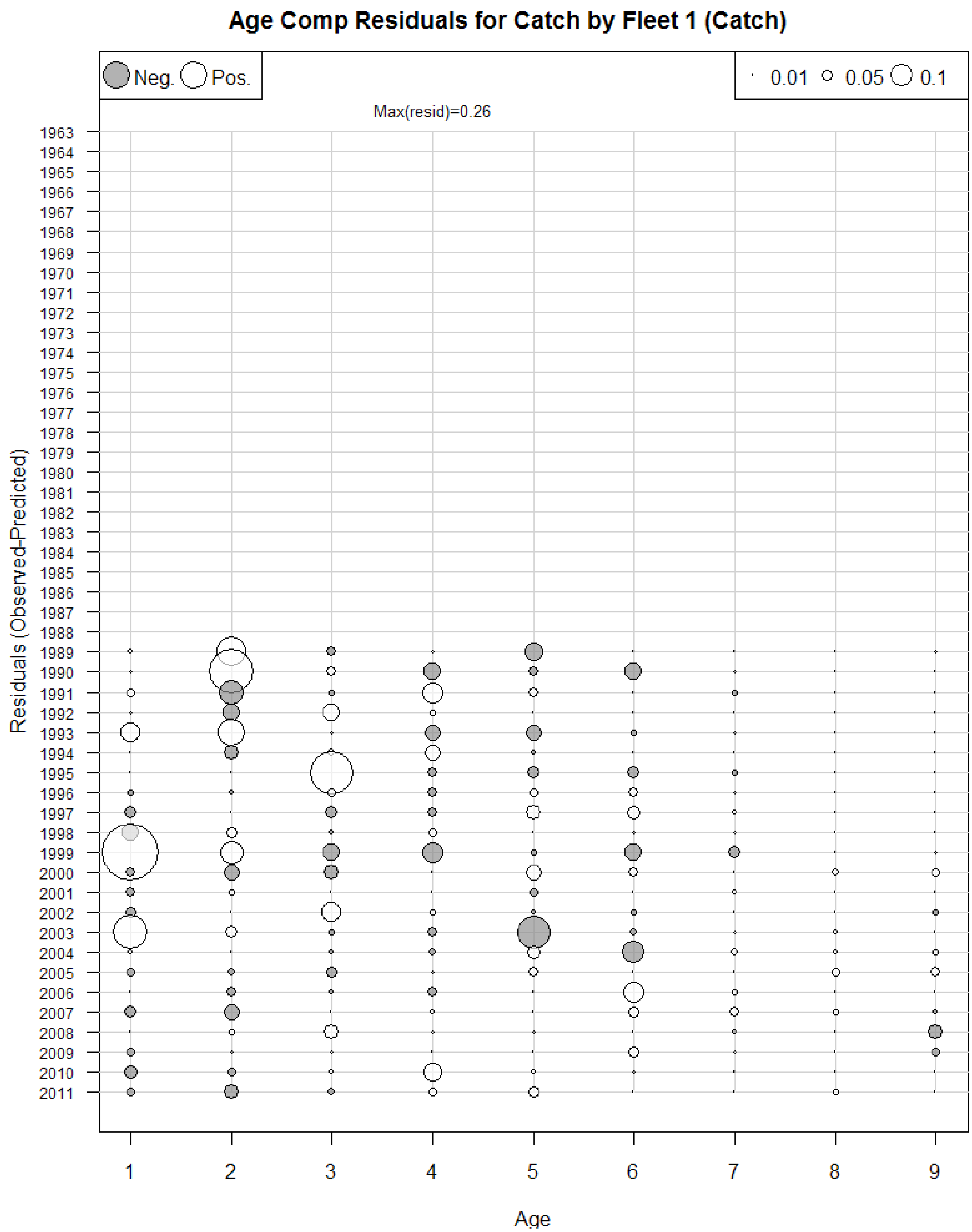


Figure B133. Age composition residuals from the commercial catch from the Base Model.

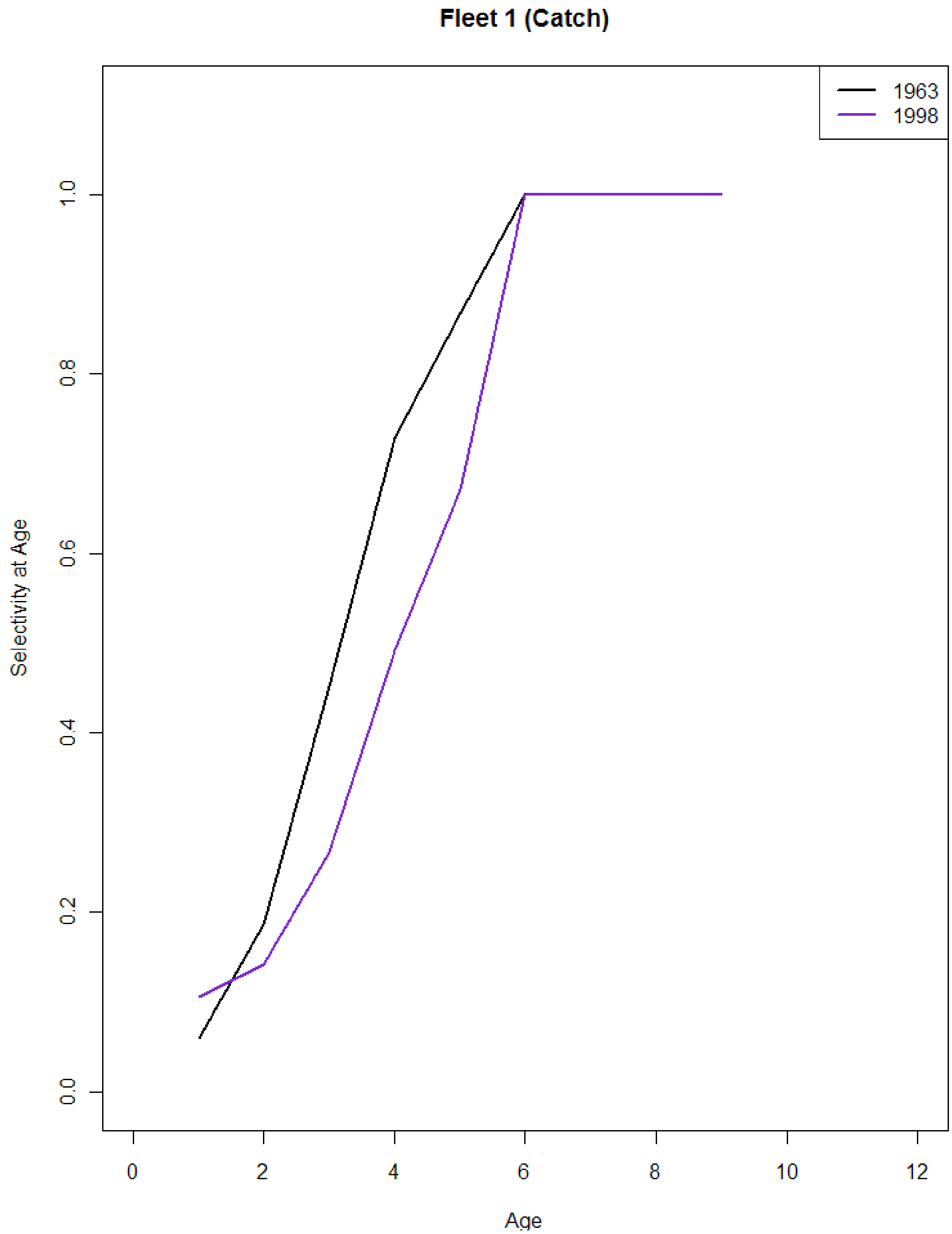


Figure B134. Selectivity patterns from the commercial fishery in tow time periods.

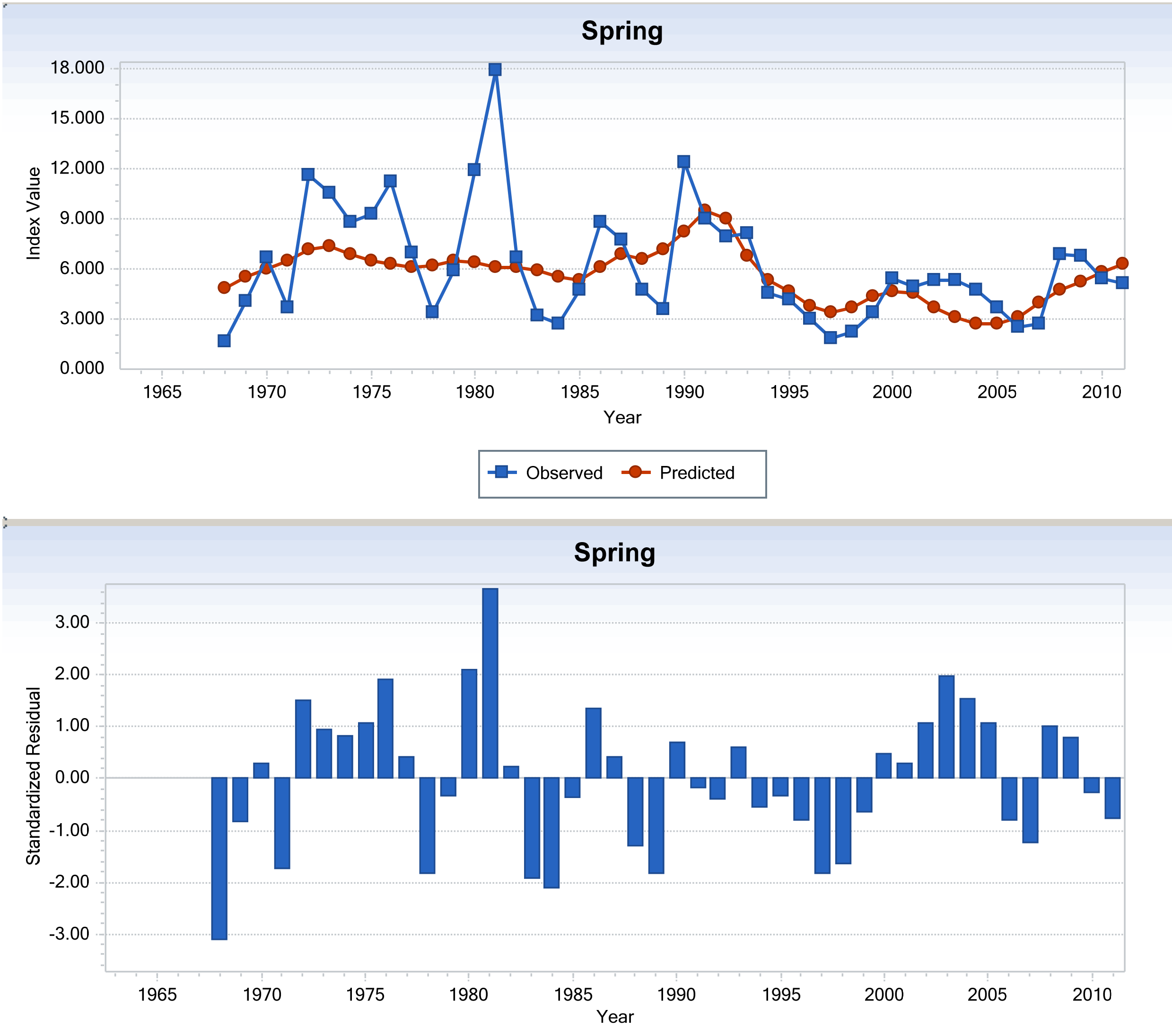
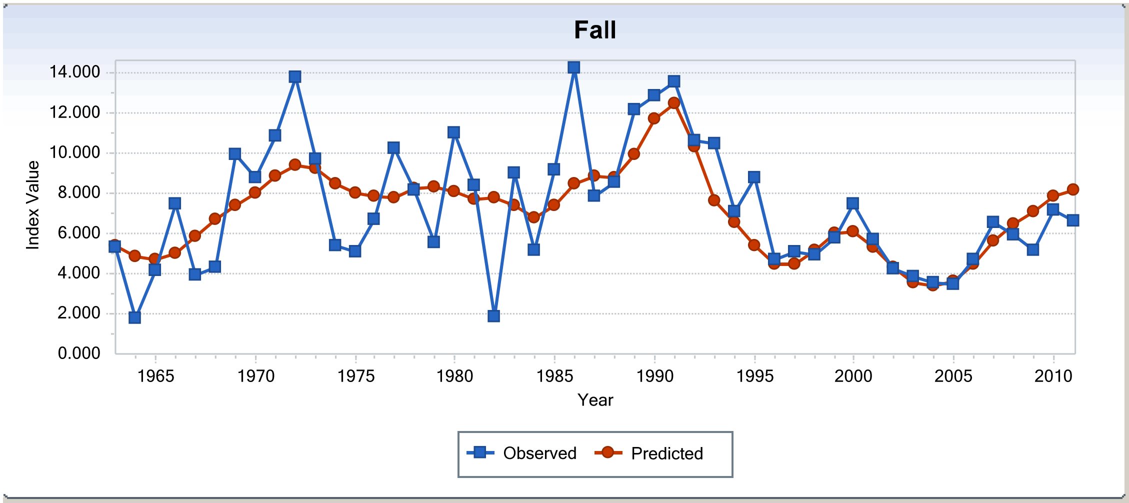


Figure B135. Residuals from the NEFSC spring survey from the Base Model.



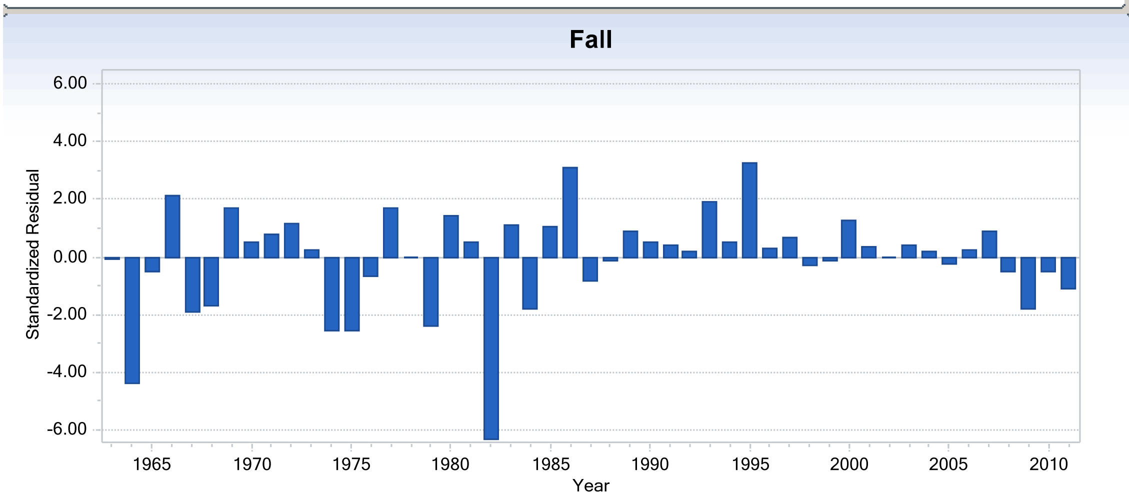


Figure B136. Residuals from the NEFSC autumn survey from the Base Model.

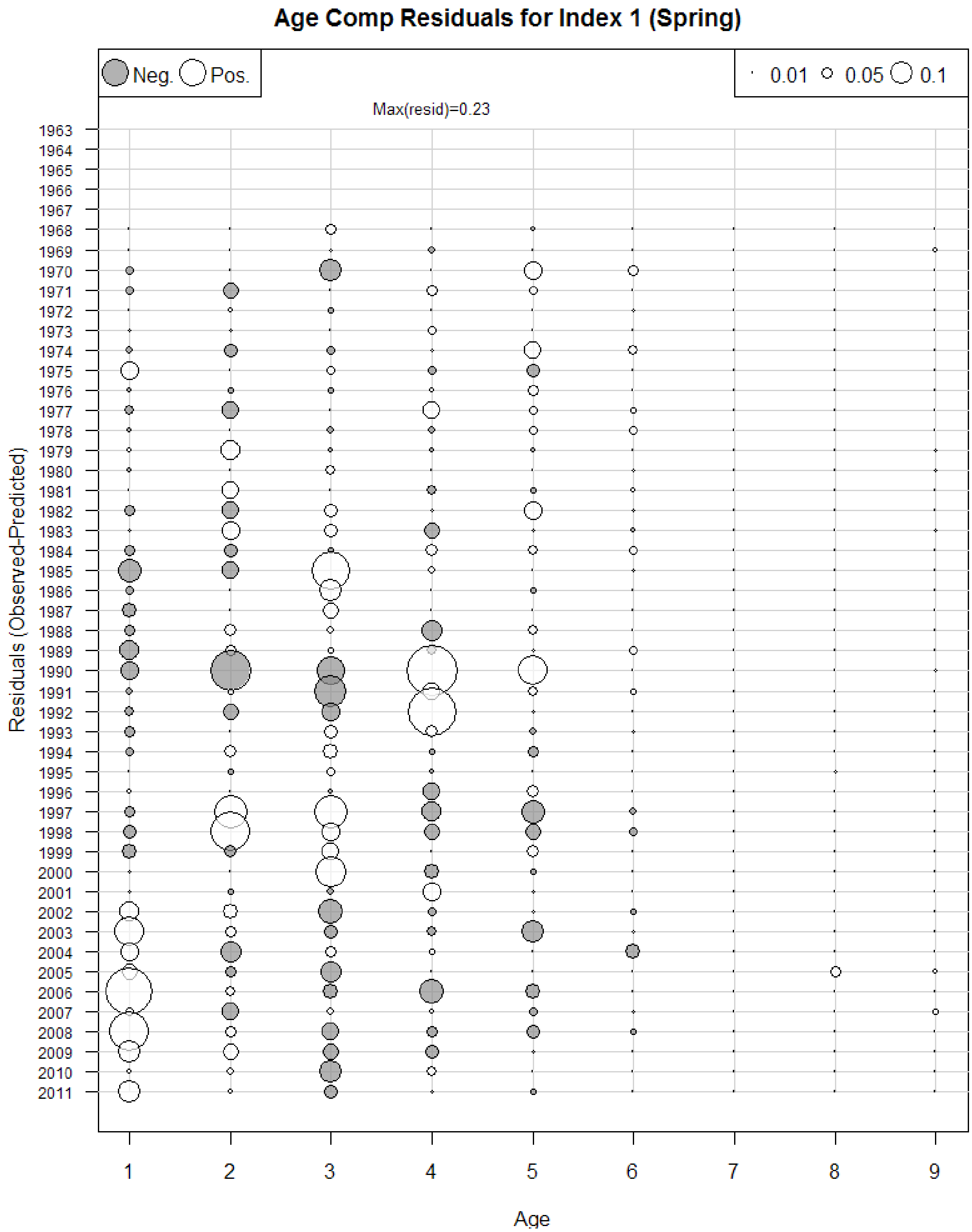


Figure B137. Age composition residuals from the NEFSC spring survey from the Base Model.

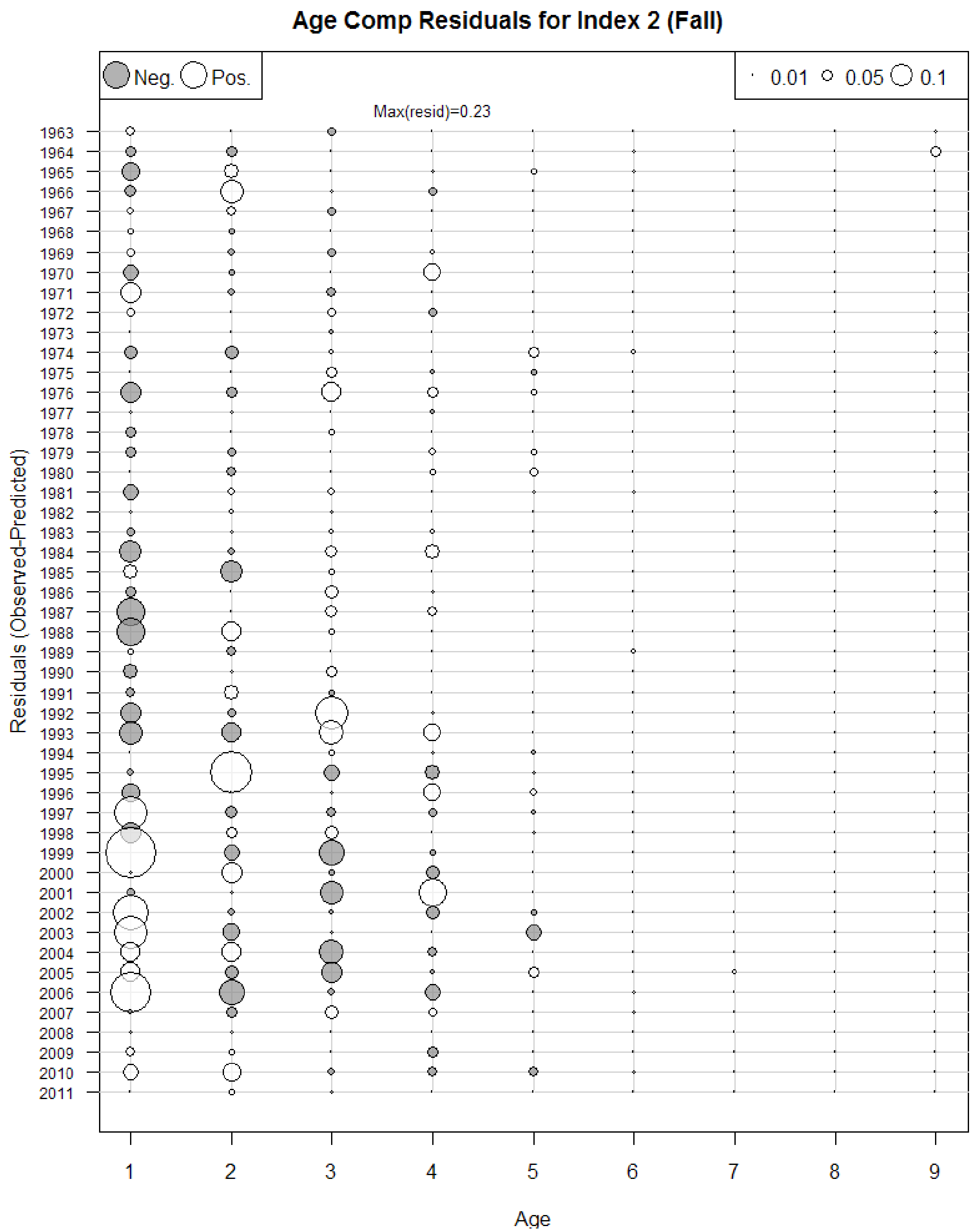


Figure B138. Age composition residuals from the NEFSC autumn survey from the Base Model.

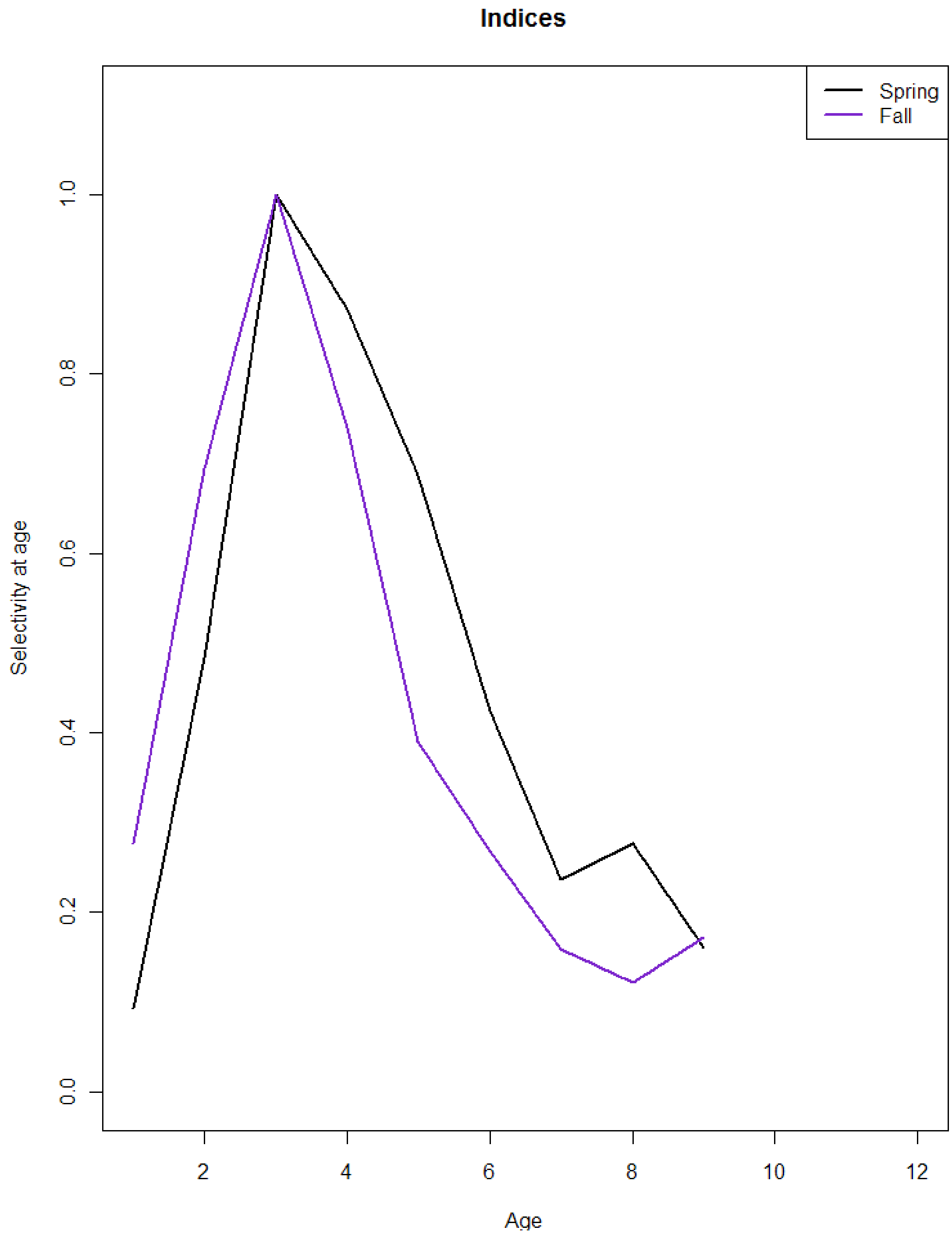


Figure B139. Selectivity for the NEFSC spring and autumn surveys estimated from the Base ASAP model.

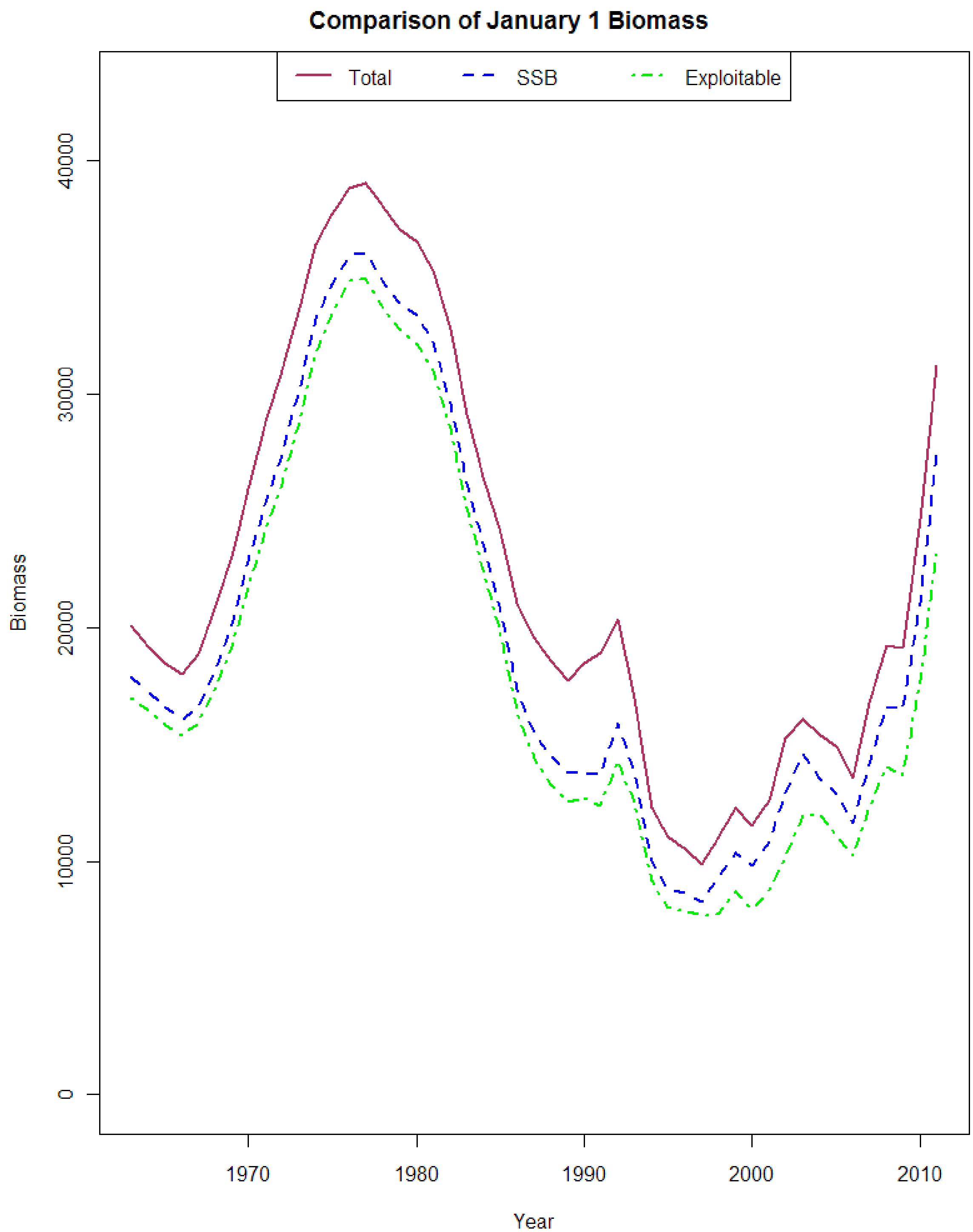


Figure B140. Estimates of January1-Biomass and Spawning Stock Biomass from the Base ASAP model.

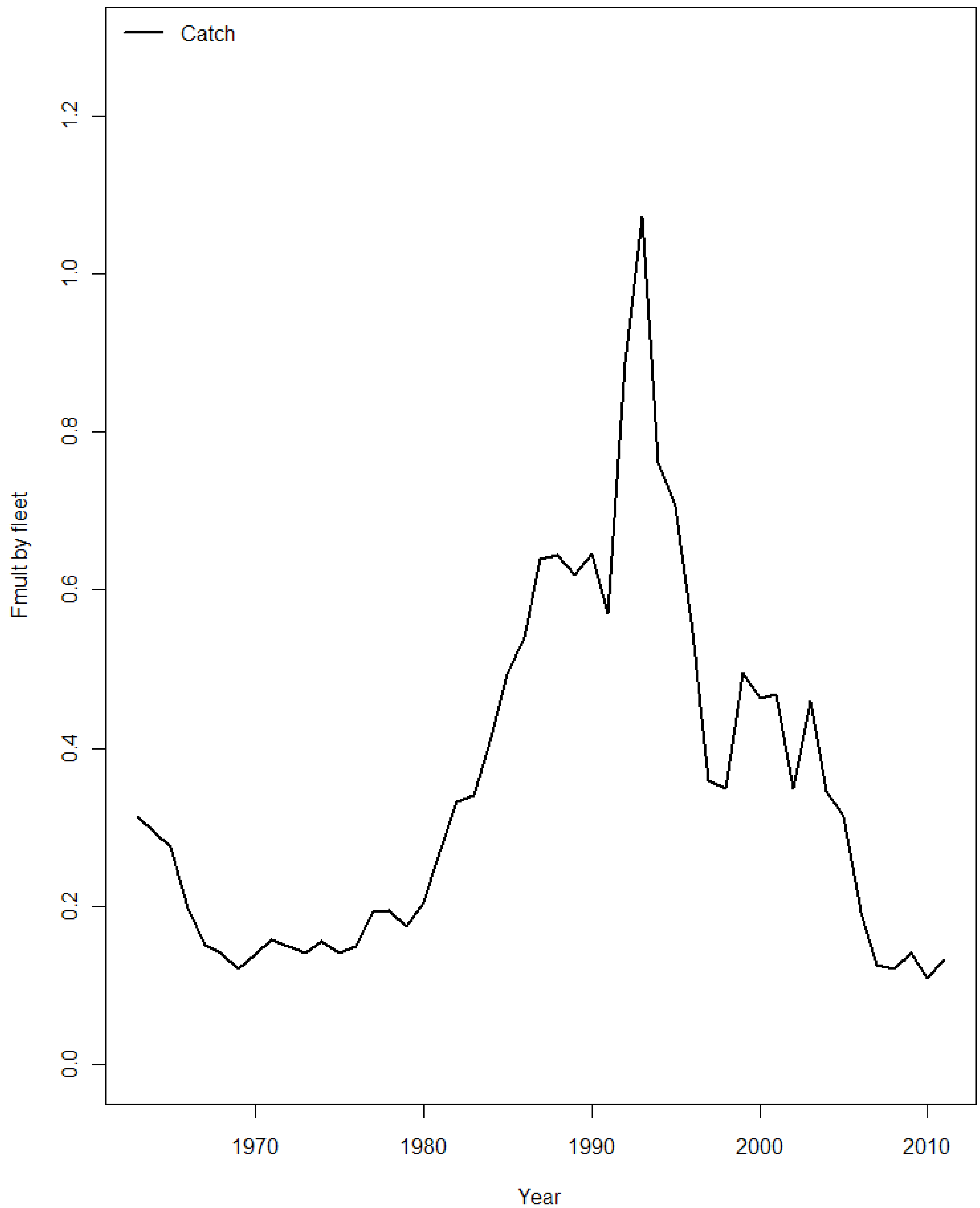


Figure B141. Estimates of fishing mortality from the Base ASAP model.

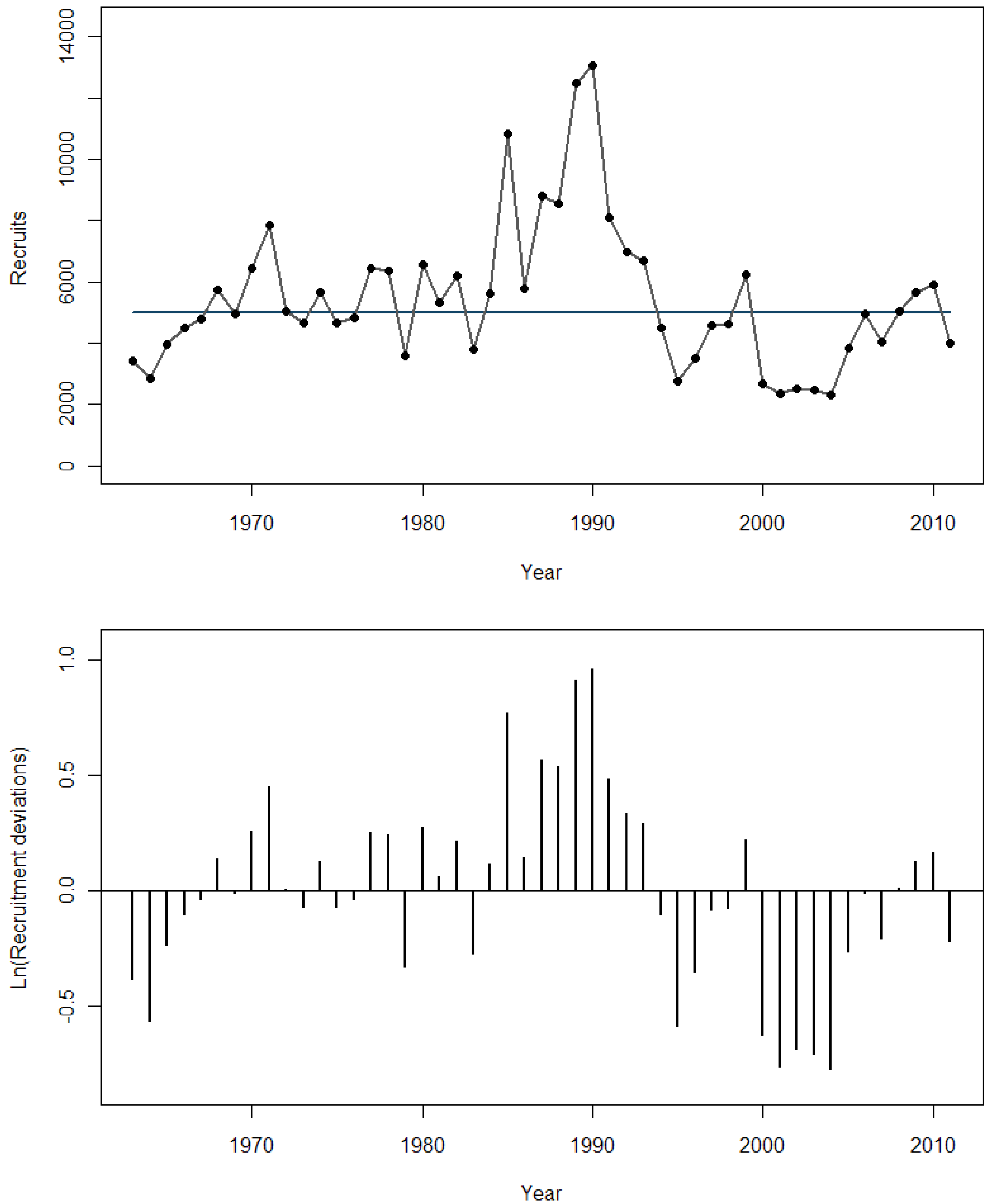


Figure B142. Estimates of recruitment (top panel) and deviations from the geometric mean (bottom panel) from the base ASAP model.

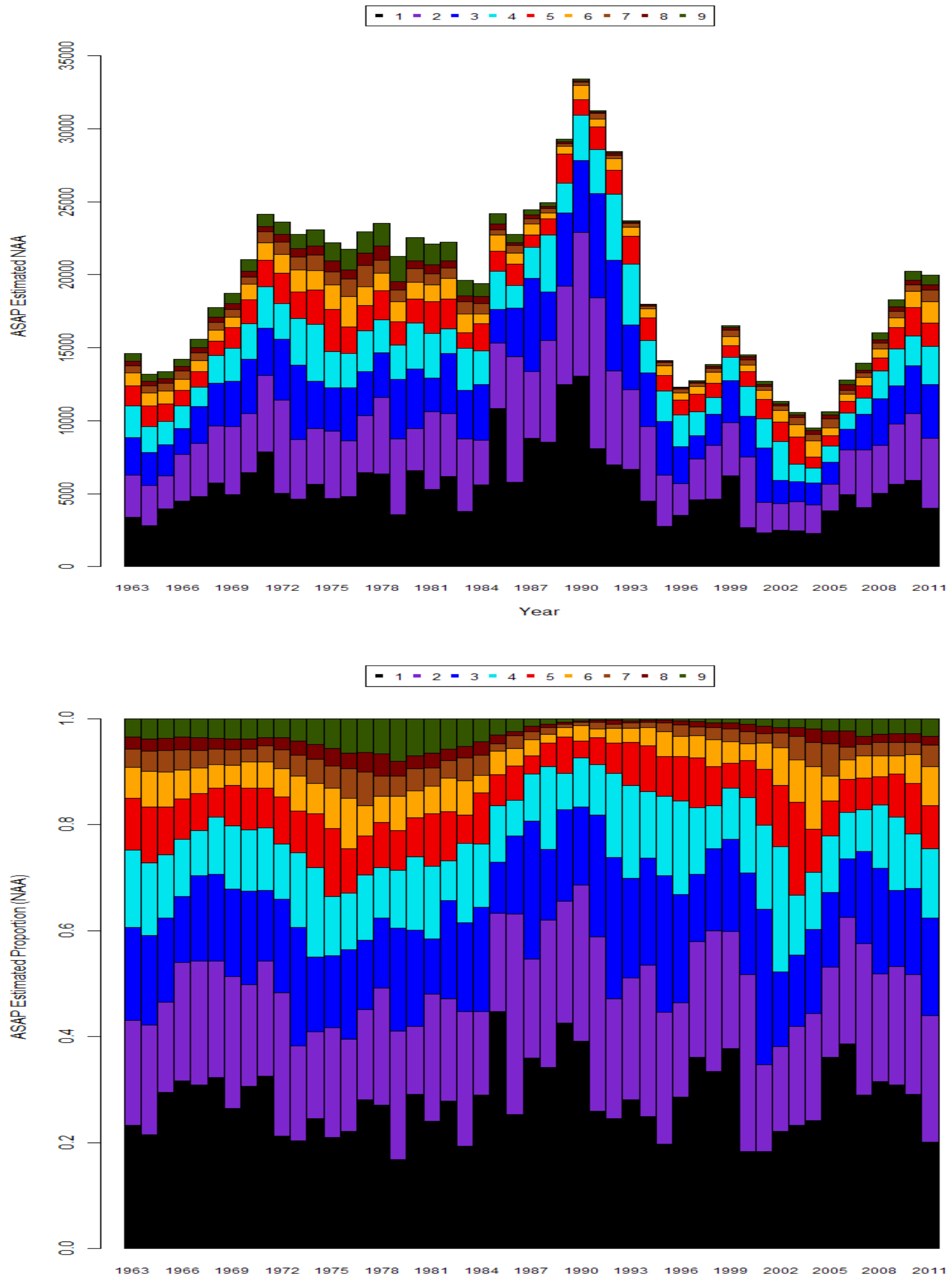


Figure B143. Numbers at age (000s, top panel) and proportion (bottom panel) from the Base ASAP model.

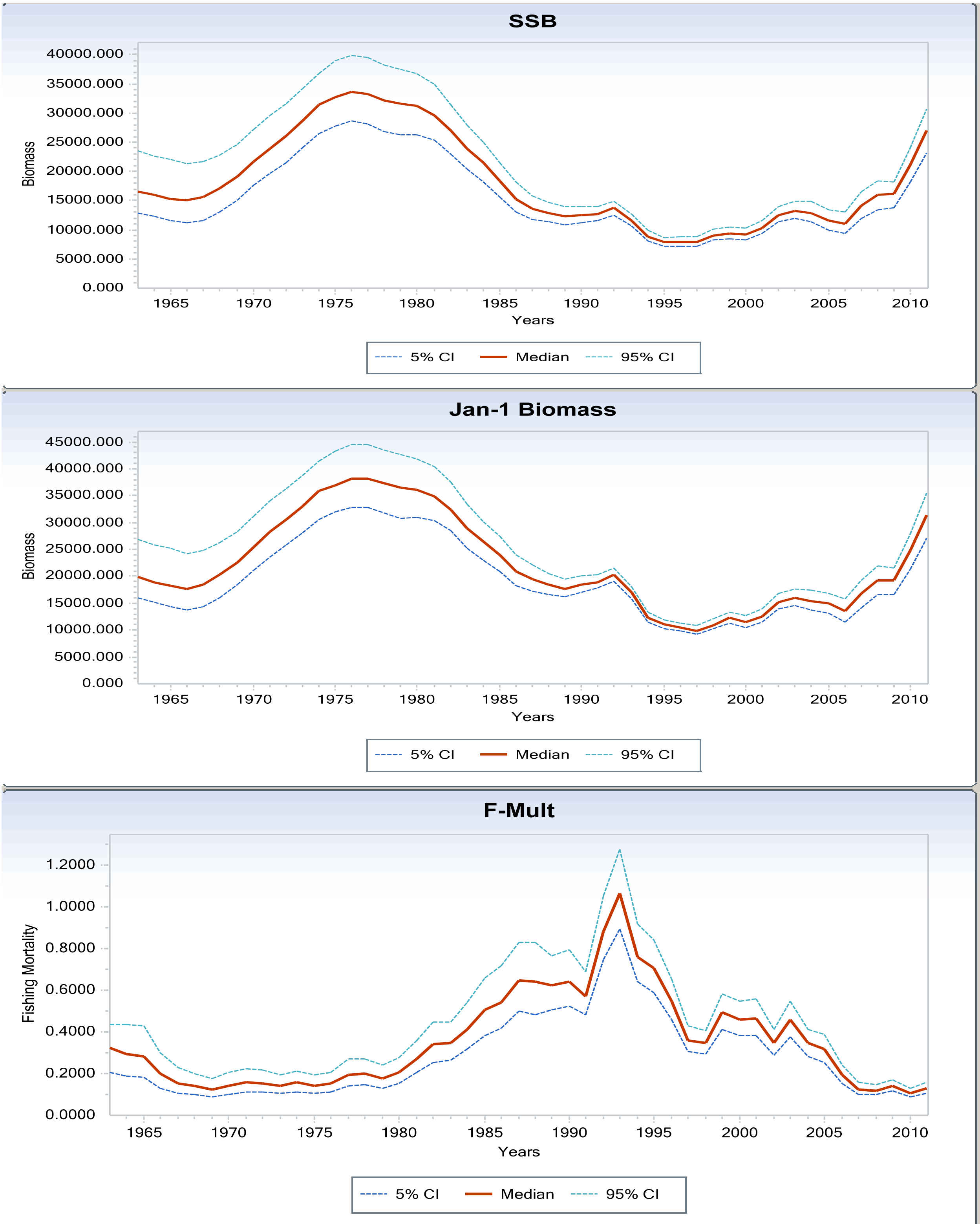


Figure B144. A 90% probability interval for white hake SSB (top panel), January 1 Biomaa (middle panel) and fishing mortality (bottom panel) fromthe Base ASAP model. The median value is in red, while the 5th and 95th percentiles are in light blue.

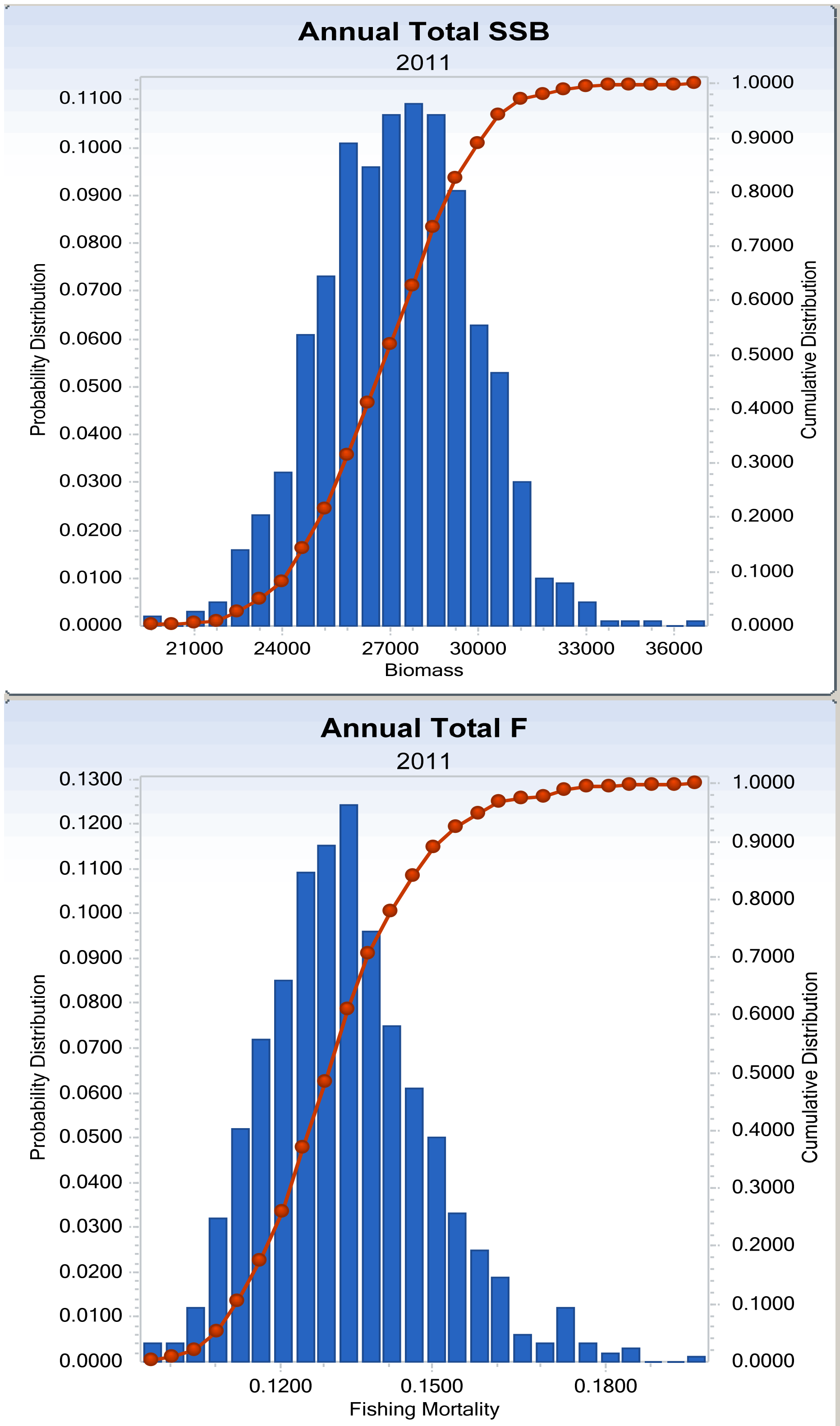

Annual Total SSB
2011
Probability Distribution
Cumulative Distribution
0.1100
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
21000
24000
27000
30000
33000
36000
Biomass
Annual Total F
2011
Probability Distribution
Cumulative Distribution
0.1300
0.1200
0.1100
0.1000
0.0900
0.0800
0.0700
0.0600
0.0500
0.0400
0.0300
0.0200
0.0100
0.0000
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0.1200
0.1500
0.1800
Fishing Mortality

Figure B145.

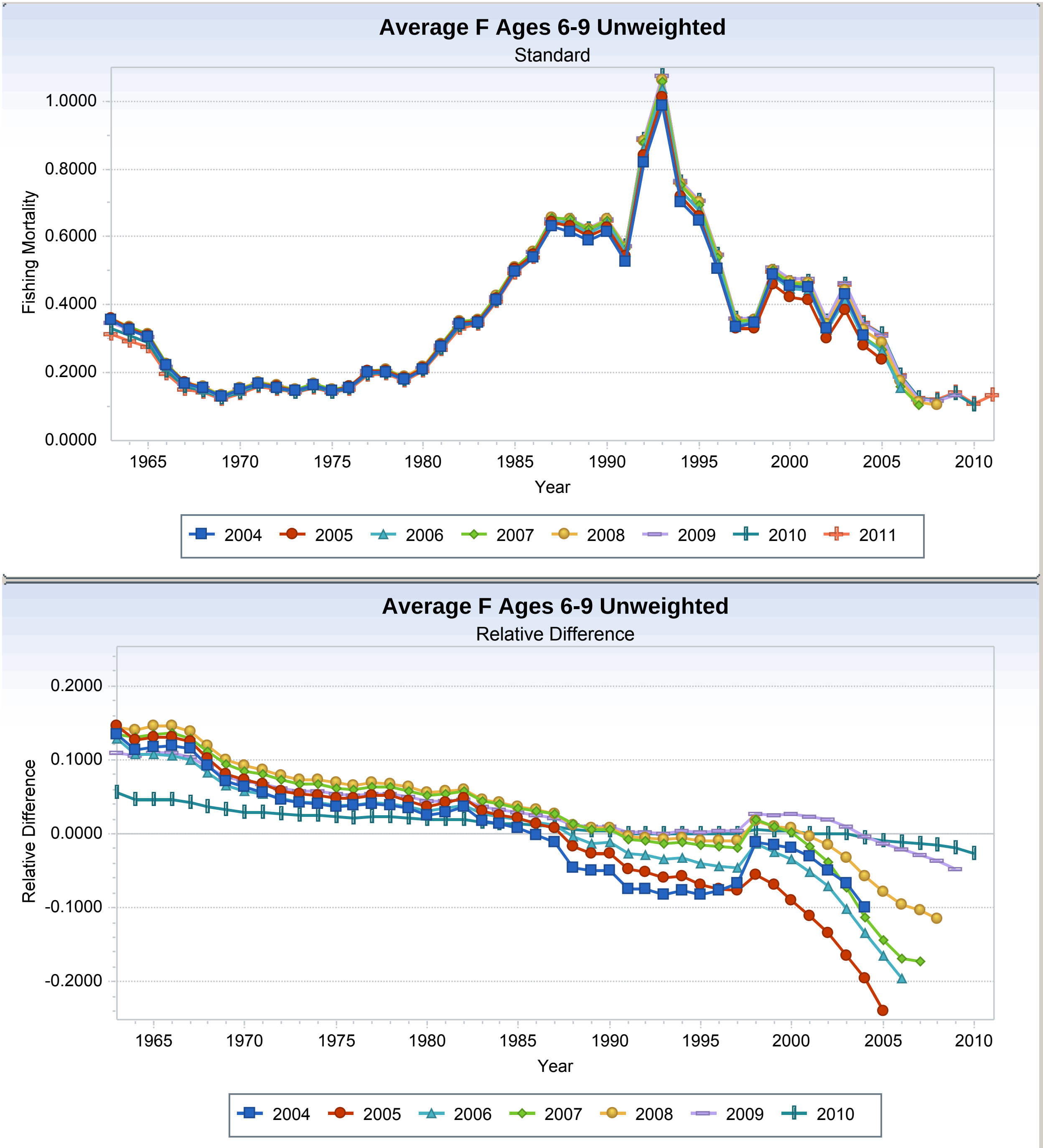


Figure B146. Retrospective plots for fishing mortality from the Base ASAP model.

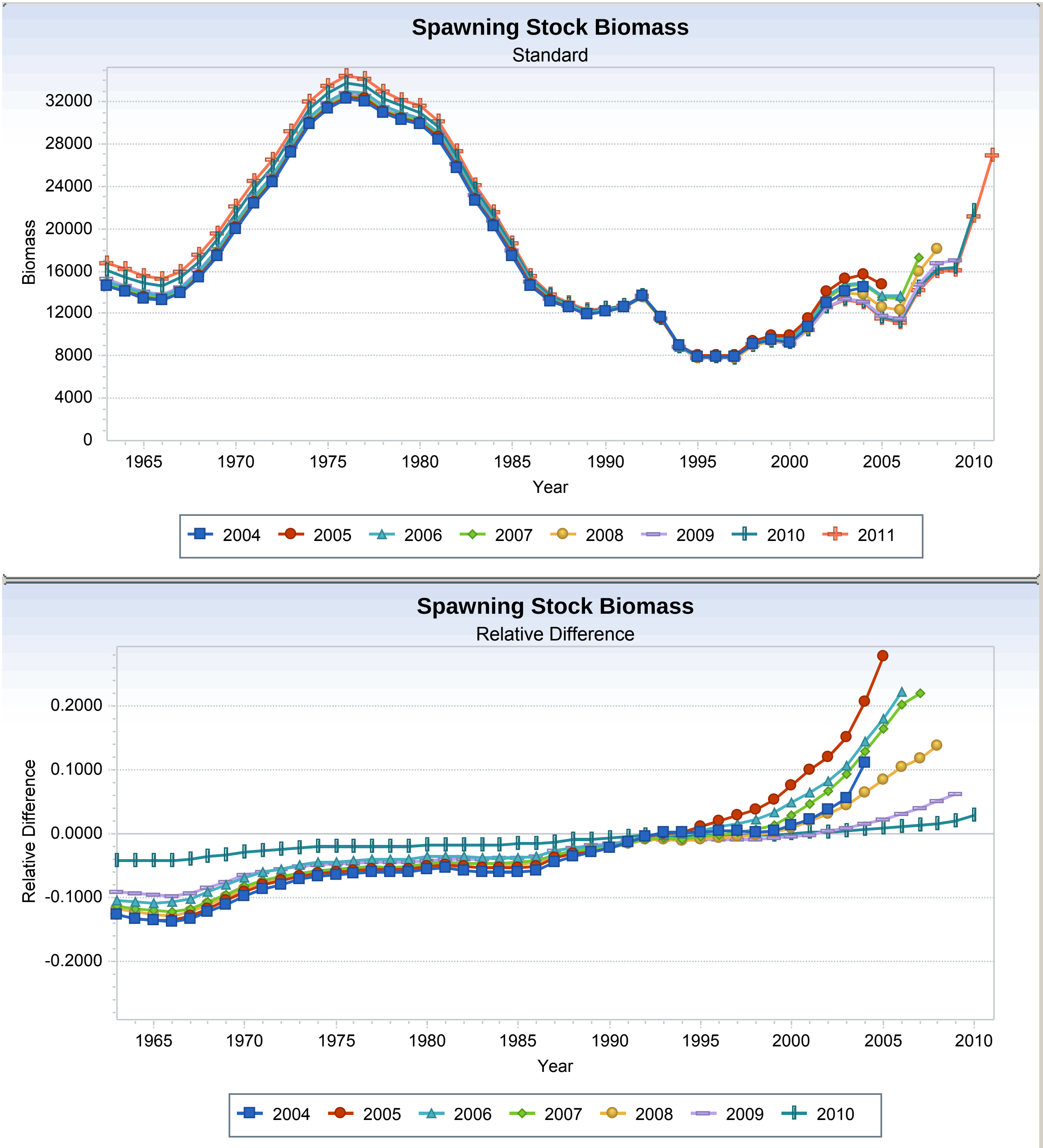


Figure B147. Retrospective plots for spawning stock biomass from the Base ASAP model.

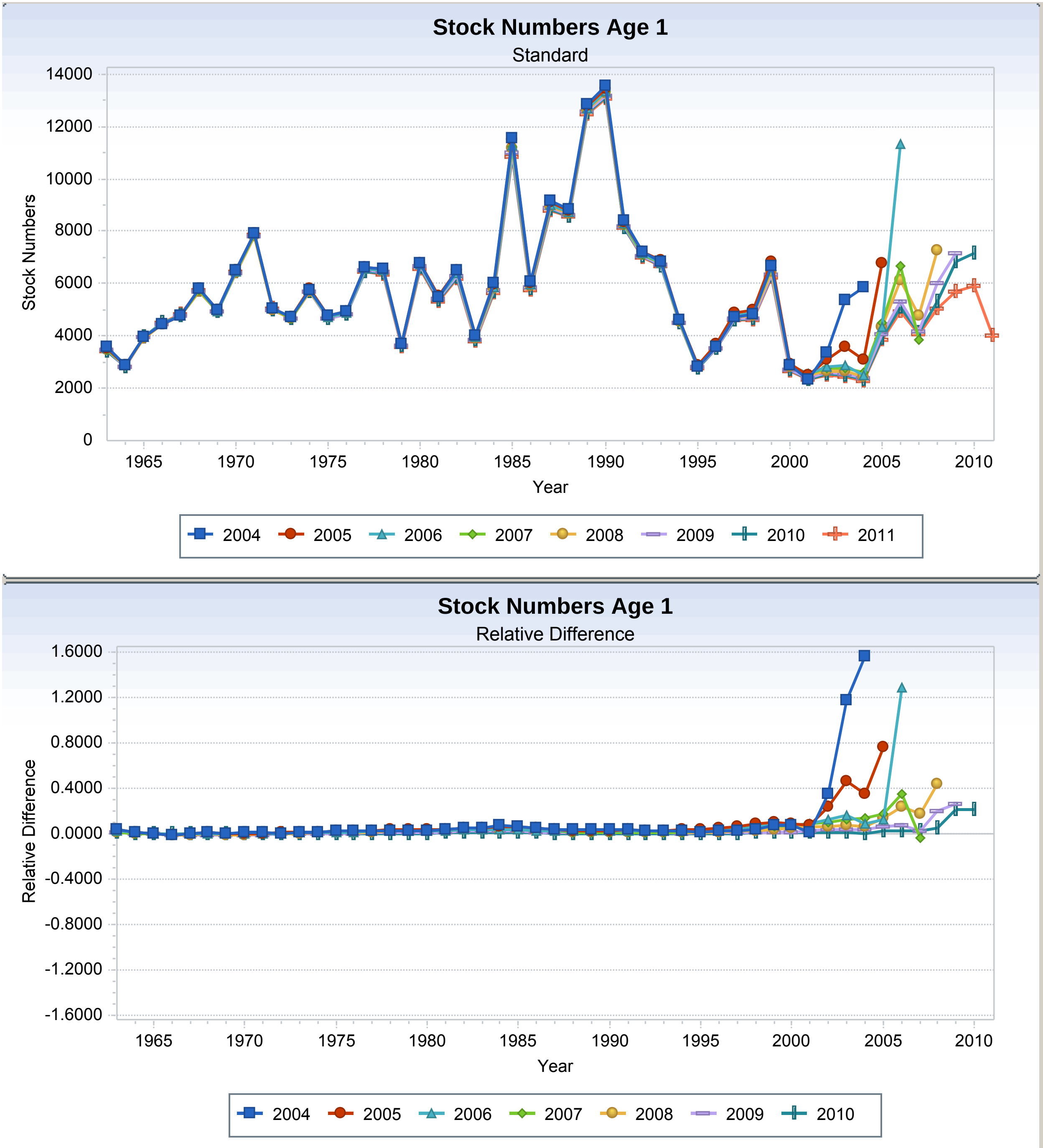


Figure B148. Retrospective plots for recruitment from the Base ASAP model.

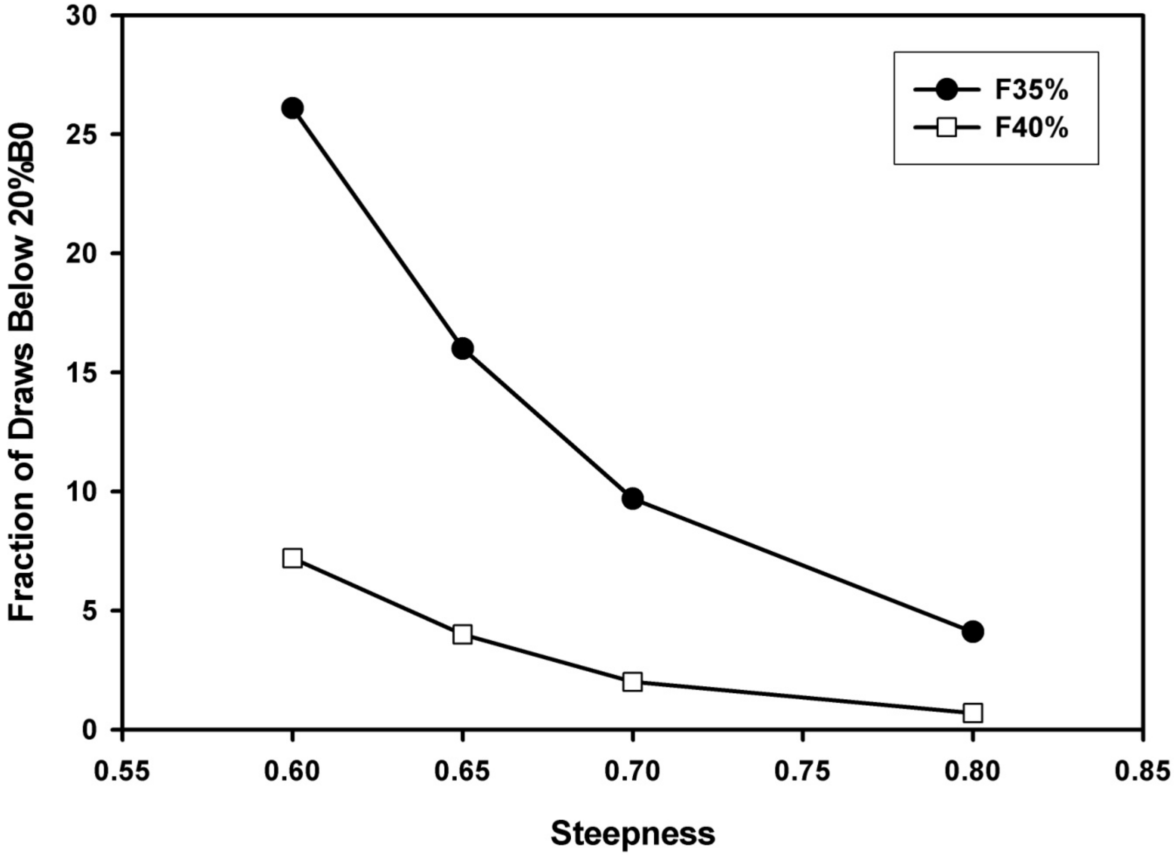
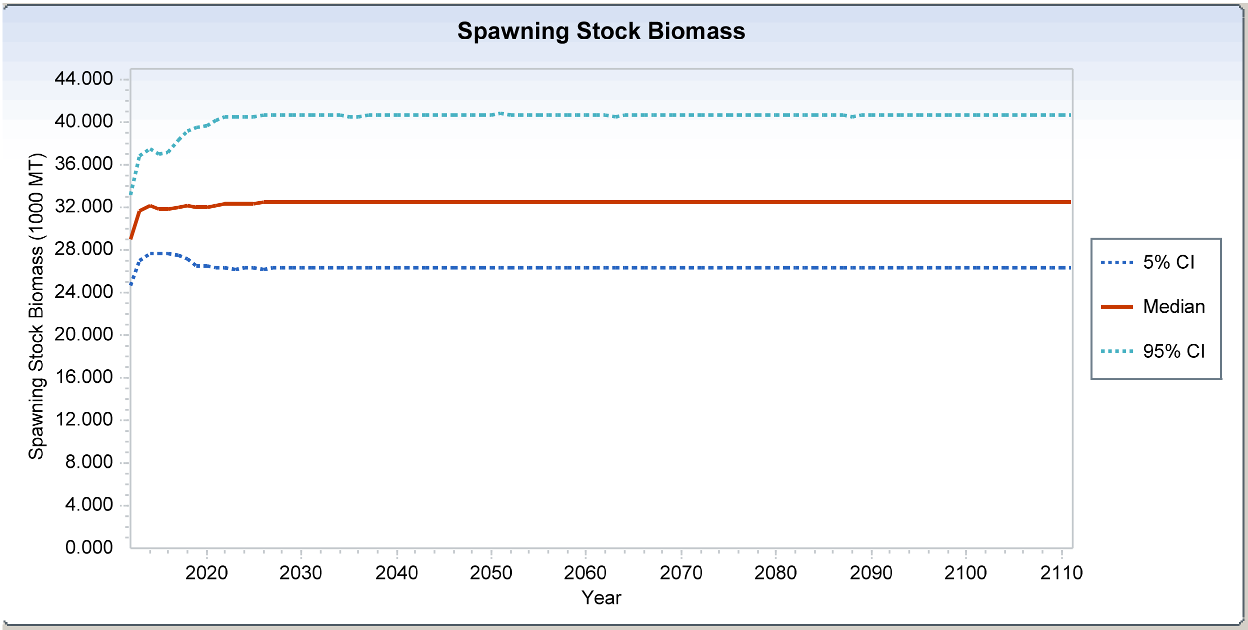


Figure B149. Analysis of the probability of falling below twenty percent Bzero using long-term projections under different recruitment assumptions.



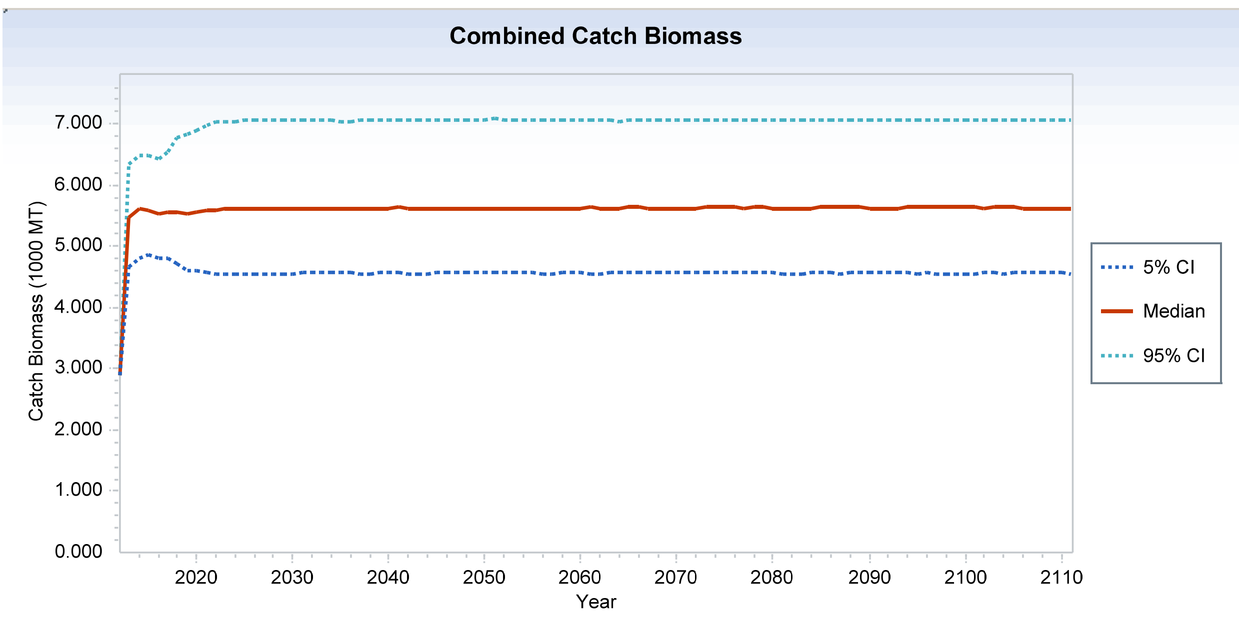


Figure B150. SSBmsy and MSY estimates from long-term projections under Fmsyproxy of 0.2.

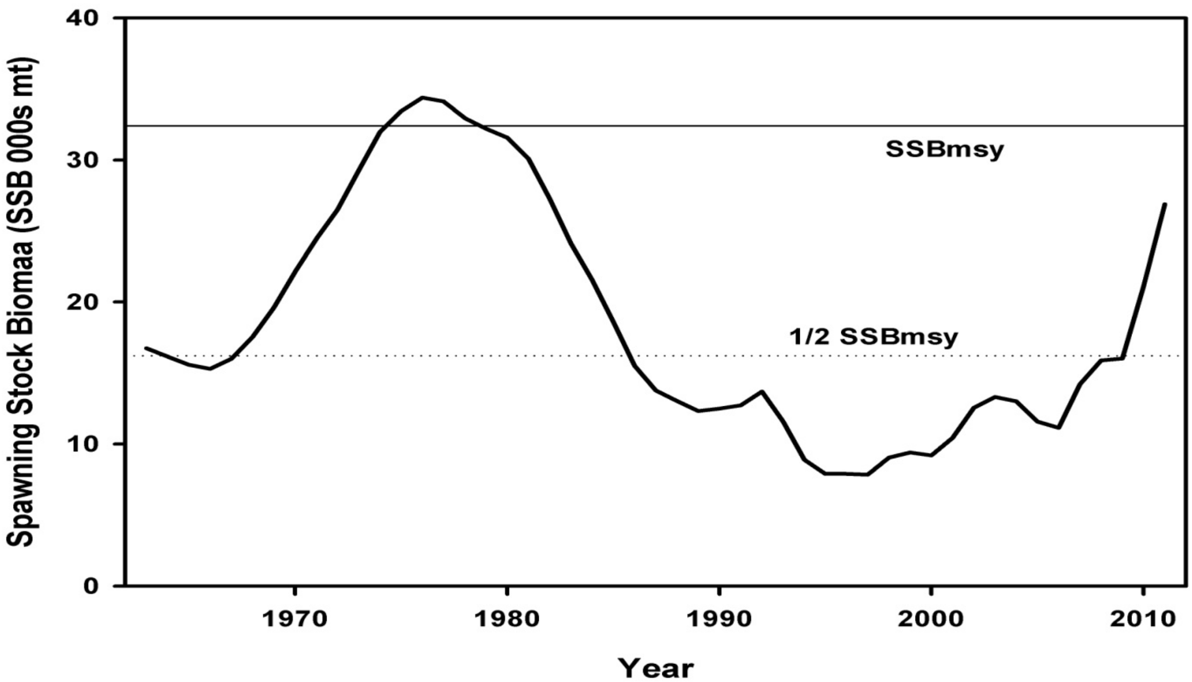


Figure B151**.** Estimated trends in the spawning stock biomass of Gulf of Maine-Georges Bank white hake between 1963 and 2011 and the corresponding SSB_{target} (SSB_{MSY}) and $SSB_{threshold}$ (1/2 SSB_{MSY}) based on the 2013 assessment.

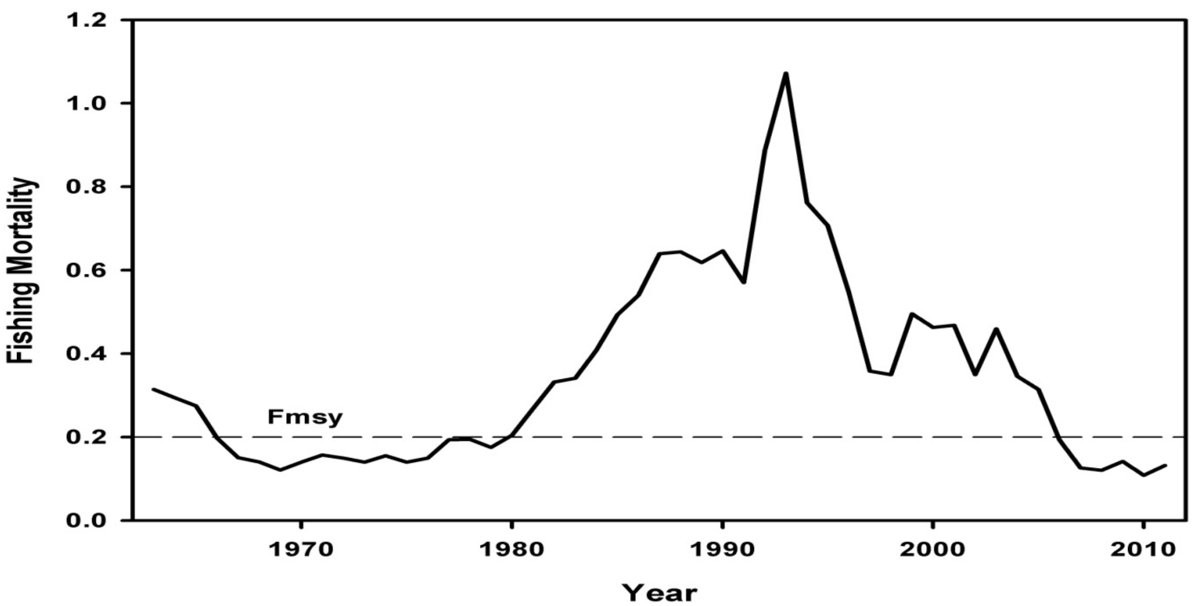


Figure B152. Estimated trends in the fully selected fishing mortality (F_{full}) of Gulf of Maine-George Bank white hake between 1963 and 2011, and the corresponding F_{MSY} based on the 2013 assessment.**Note that the time series includes two selectivity blocks (1963-1997, 1998-2011) and the F_{full} values are not comparable between blocks.*

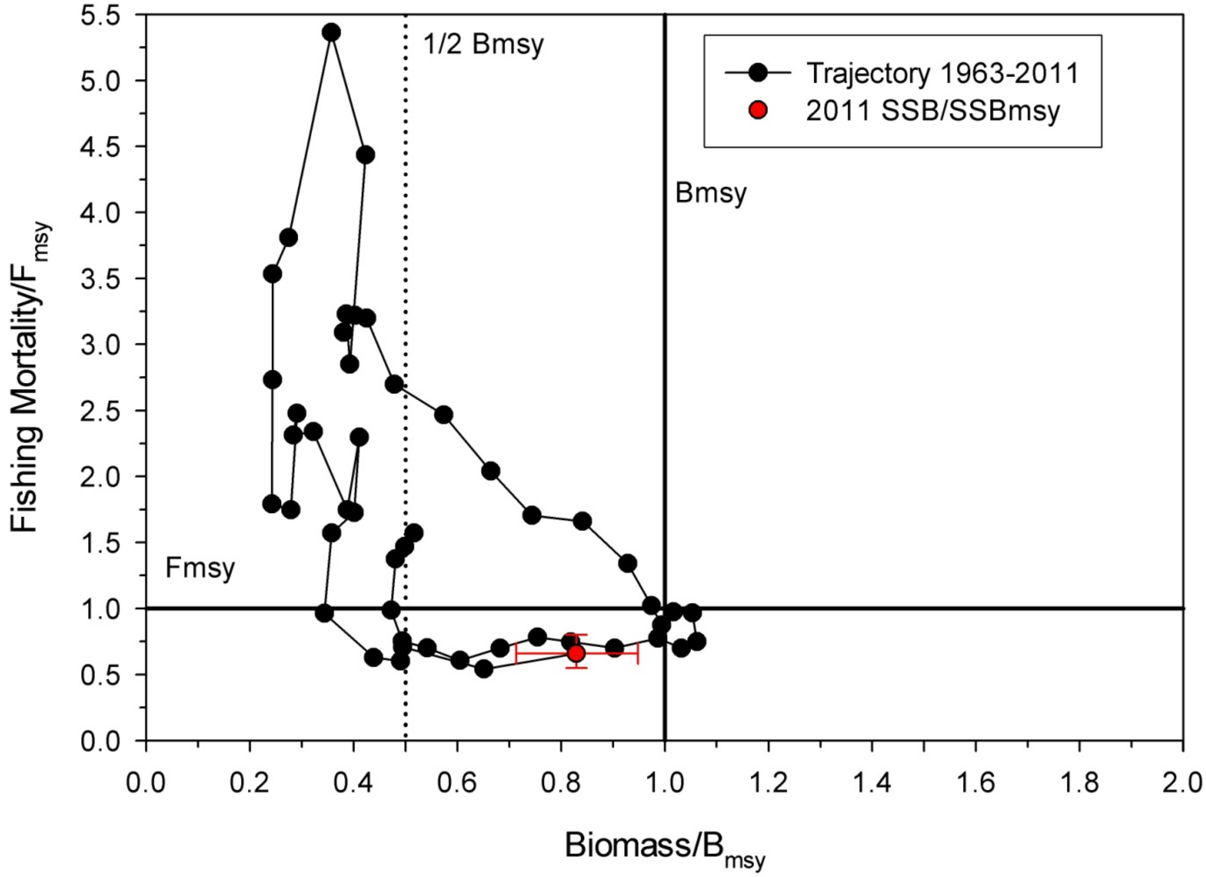


Figure B153. Stock status of Gulf of Maine-Georges Bank white hake for 2011 relative to MSY reference points for spawning stock biomass (SSB) and fishing mortality (FFull); 2011 estimate is the colored dot, error bars represent 90% posterior probability intervals. Gray dotted line is the
1963-2010 time series ratio of SSB to SSBmsy based on 2012 MSY reference points.

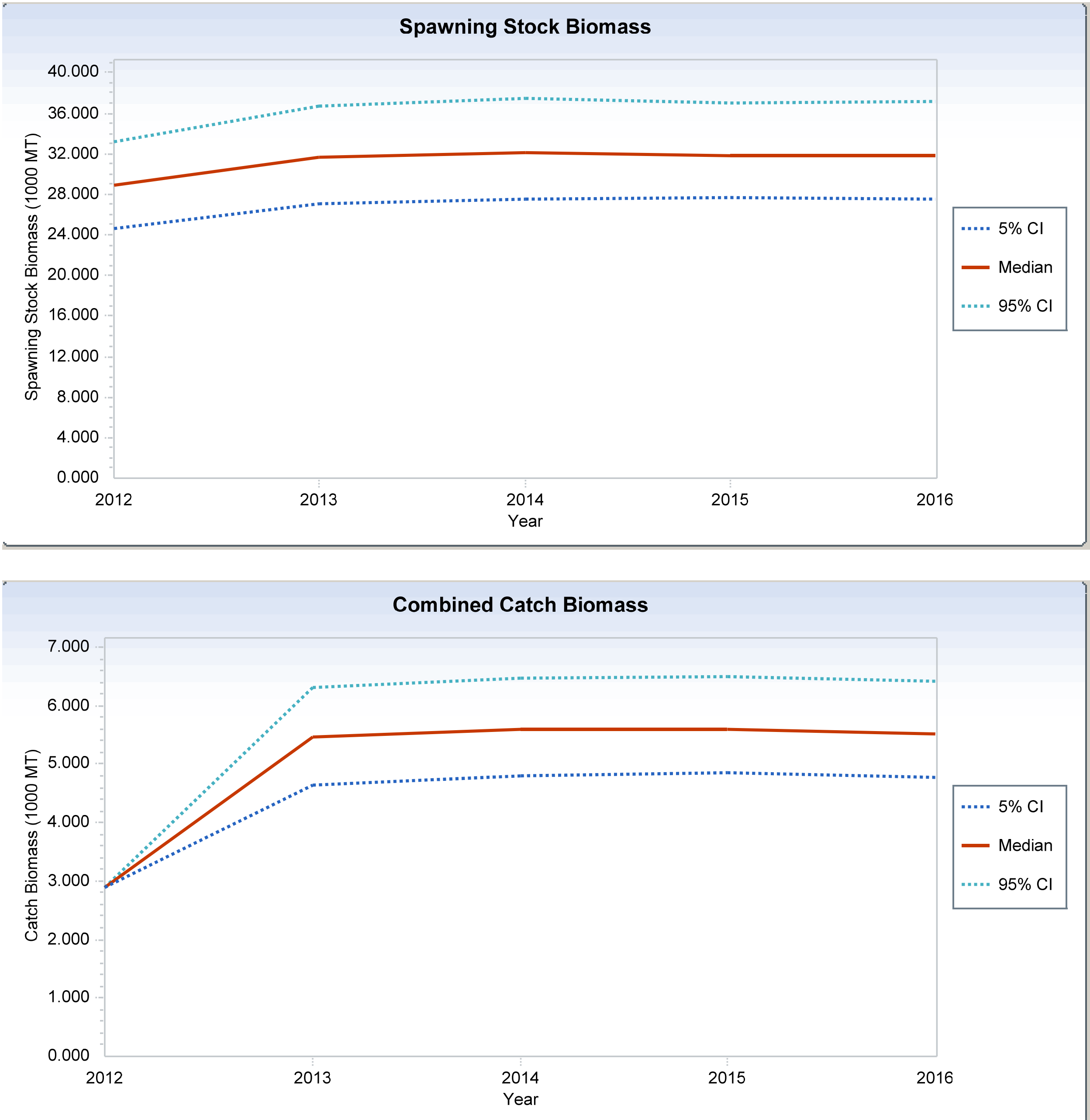
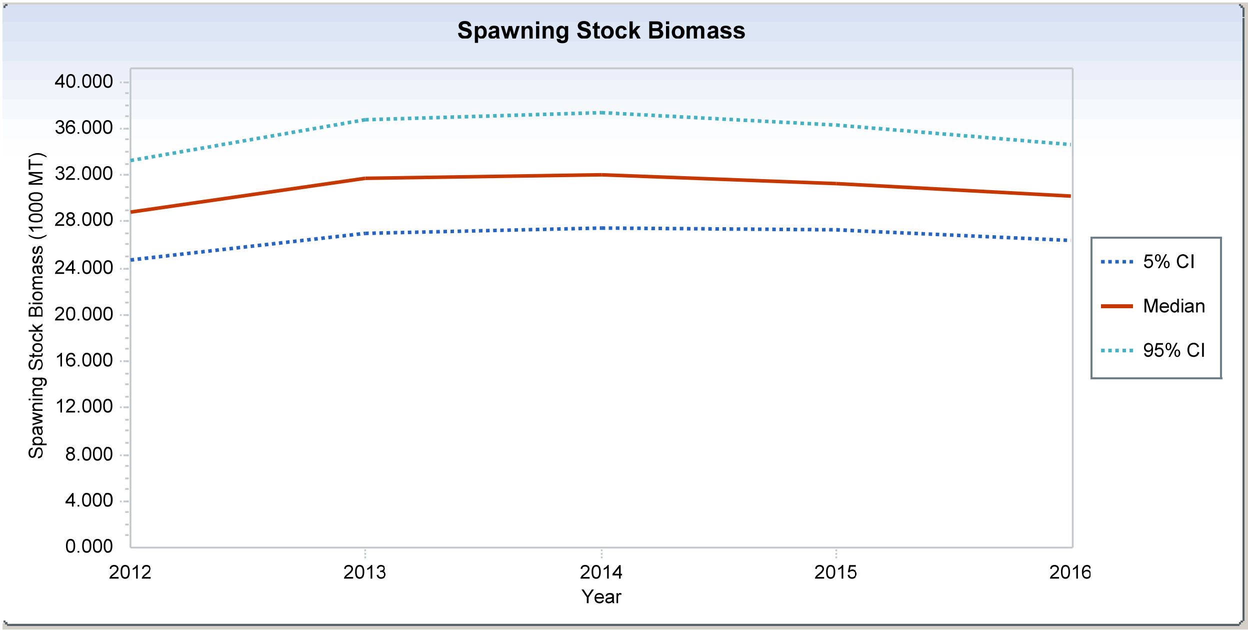


Figure B154. Short-term projections under F40 using the long time series of recruitment values (1963-2009).



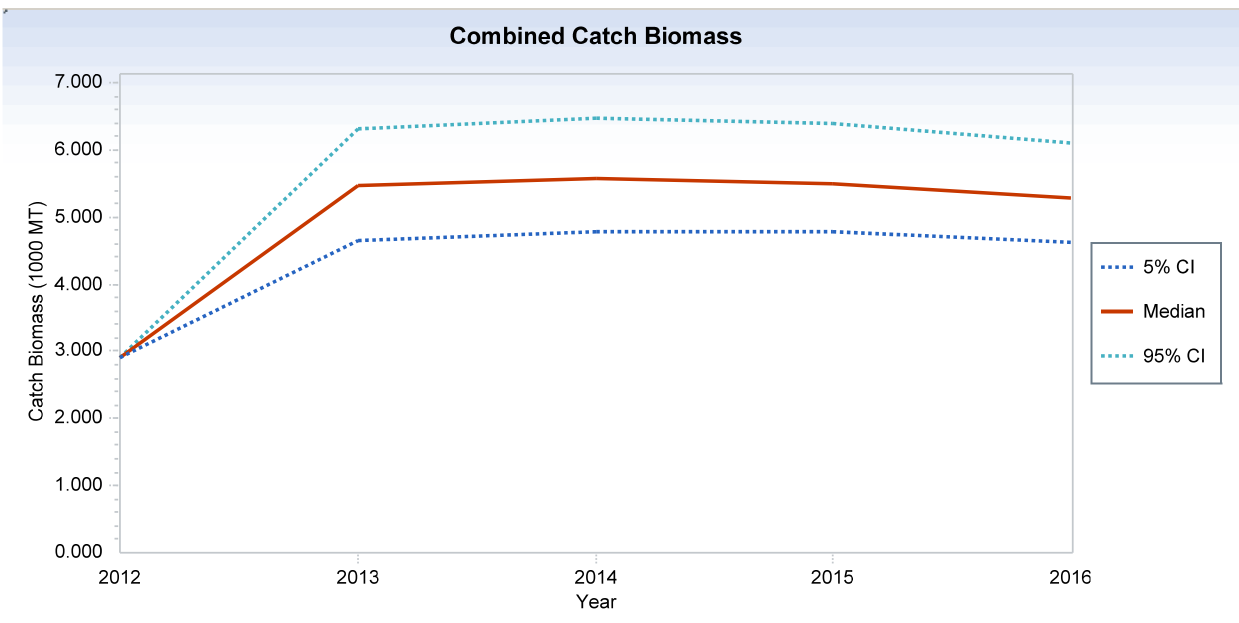


Figure B155. Short-term projections under F40 using the long time series of recruitment values (1963-2009).

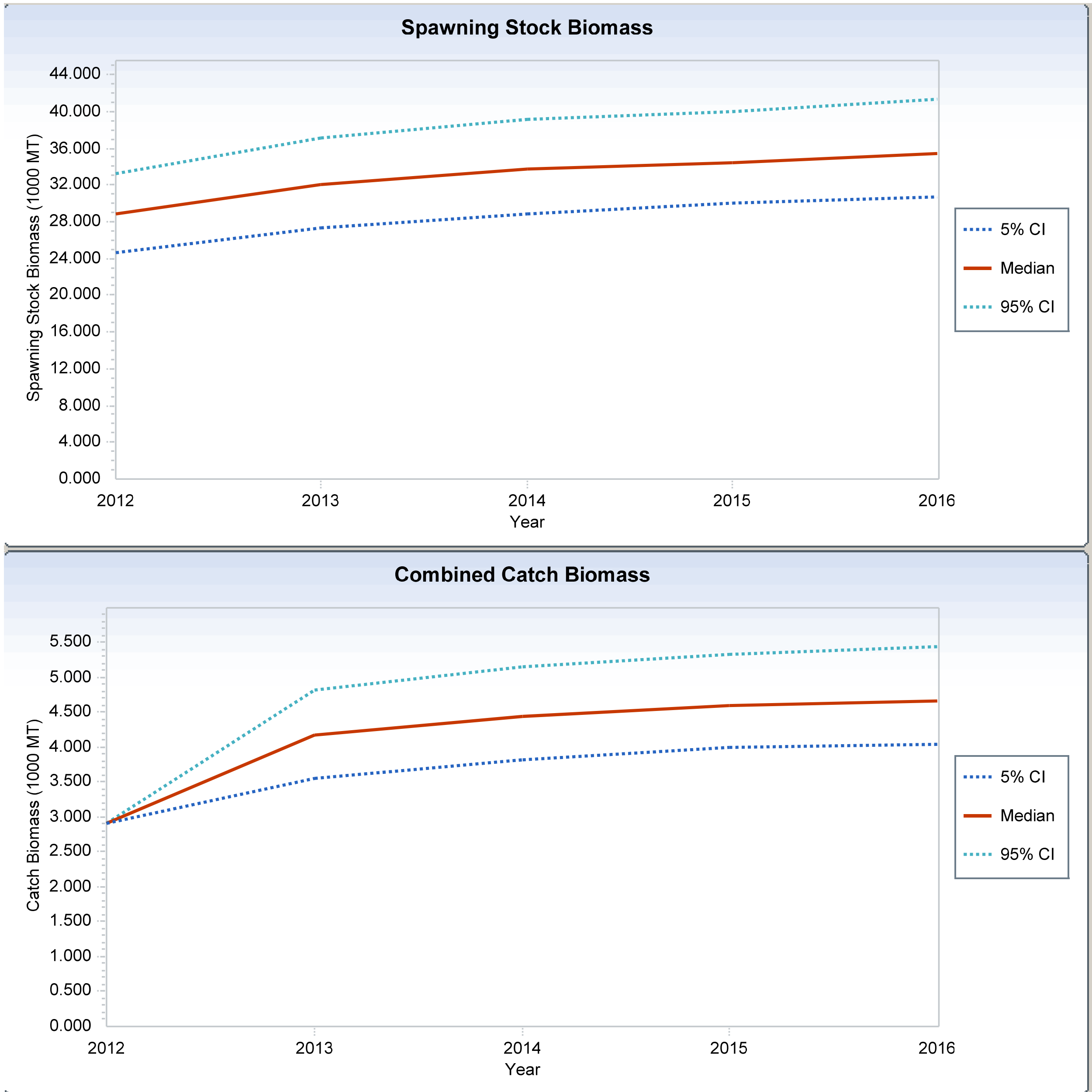
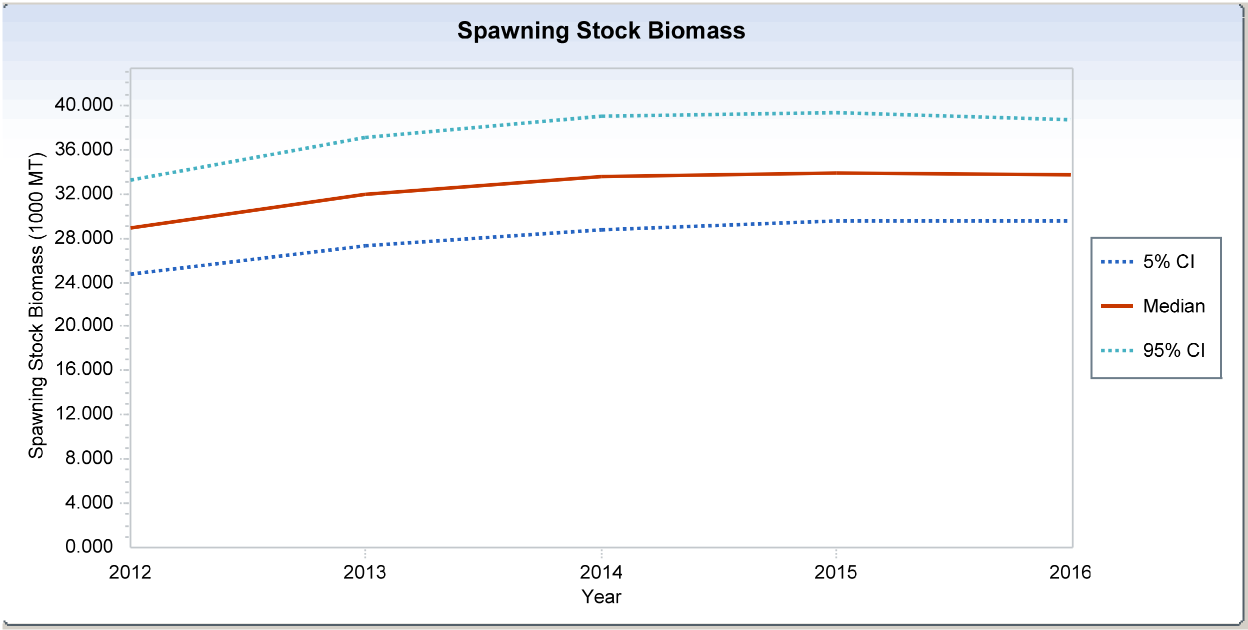


Figure B156. Short-term projections under 75%F40 using the long time series of recruitment values (1963-2009).



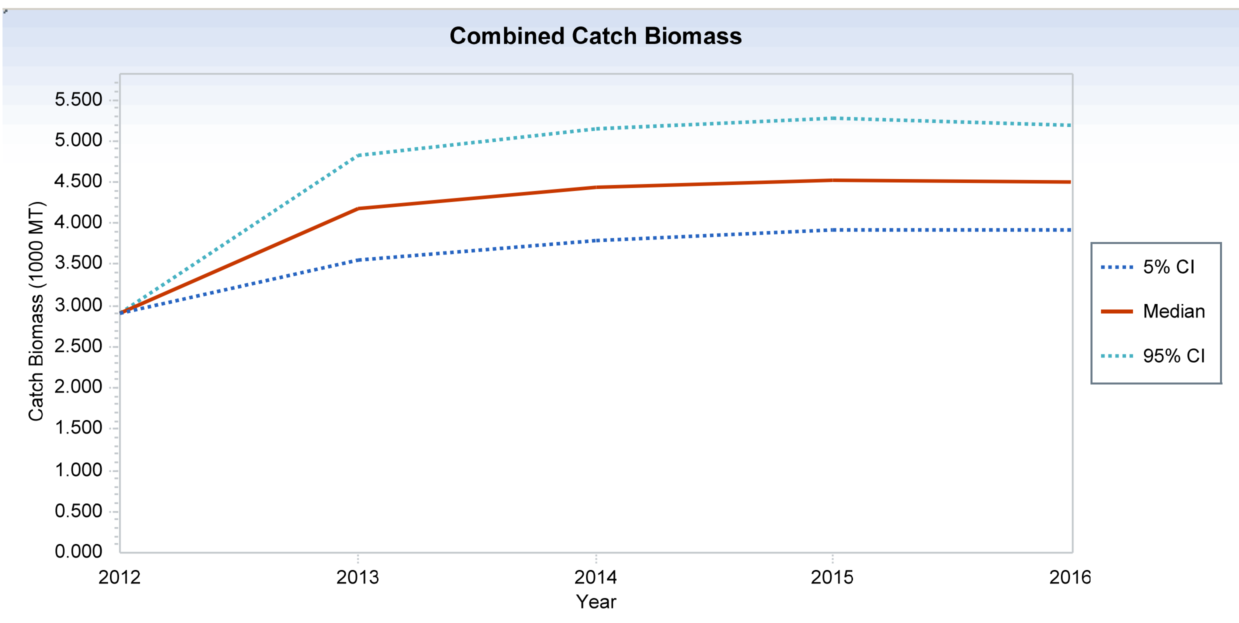


Figure B157. Short-term projections under 75%F40 using the short time series of recruitment values (1995-2009).

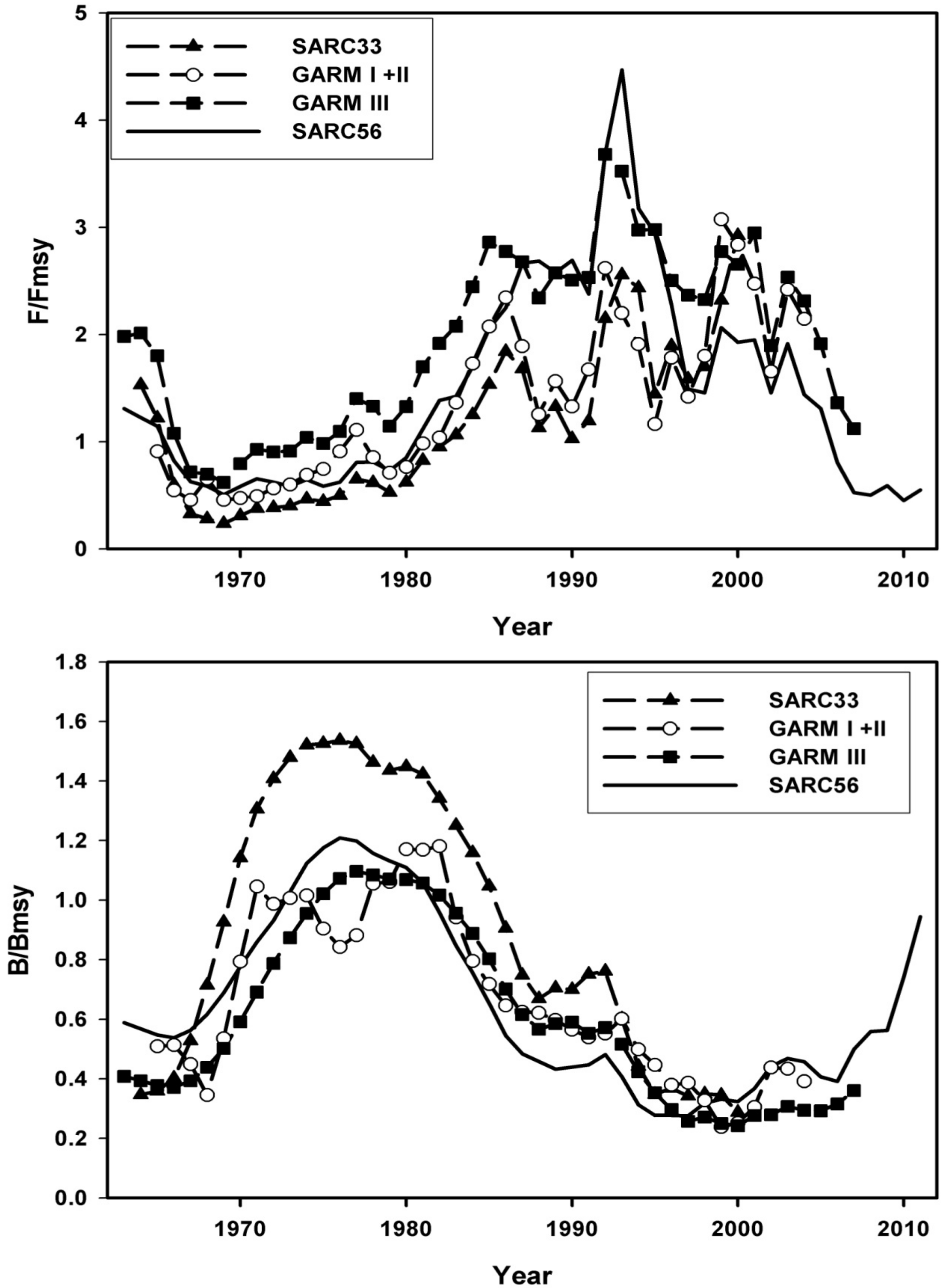


Figure B158. Historical retrospective of F/Fmsy and B/Bmsy from SARC33 (ASPIC model), GARM I and II (AIM), GARM III (ASPM) and SARC 56 (ASAP).

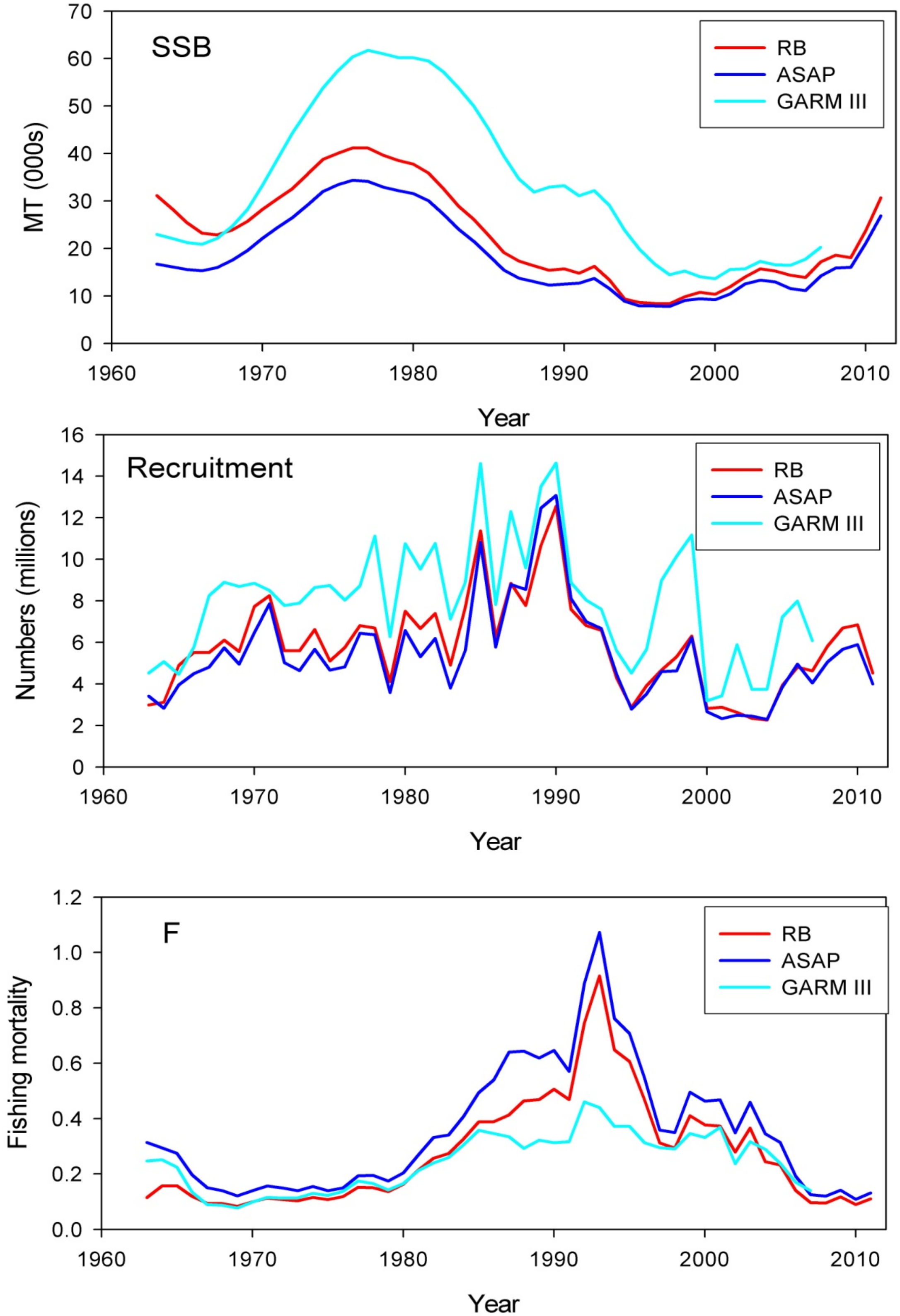


Figure B159. Comparisons of the ASPM (RB), the current ASAP, and the 2008 GARM III model.

Appendix B1. Exploration of the Statistical Catch-at-Age

Data and Methodology

The algebraic details of the methods used for the SCAA assessments and BRP estimation are set out in Appendix B2.

The following changes have been made from "2011 - new data" assessment with which the bridge-building exercise culminates to provide the provisional new Reference Case assessment “RCp”:

9. Baranov catch equation instead of Pope's approximation.
10. Survey season: spring and autumn instead of begin and mid-year (equation B2.9).
11. Survey variance: use input CV's and estimate additional variance (equation B2.16), instead of estimate year-independent variance.
12. ϕ estimated instead of fixed at 0.2.
13. μ_{spawn}=0.25 instead of 0.1667 (equation B2.6).
14. Use age-dependent σ_a for CAA (equations B2.18 and B2.21).
15. Flat commercial selectivity from age 6.
16. Commercial selectivity blocks (1963-1997, 1998-2011).

The first six of these changes are either necessitated by changes to or more accurate representation of input information, together with advances made since GARM III in the assessment methodology applied to other stocks in the region such as Gulf of Maine cod (see e.g. Butterworth and Rademeyer 2012). The necessity for change 6 in the case of white hake was confirmed through the use of AIC. Changes 7 and 8 eventuated from specific analyses for the preliminary white hake data. Regarding 7, freeing the parameter concerned resulted in only a very weak dome in the commercial selectivity vector, and little improvement of the likelihood or changes in key results compared to keeping selectivity flat at larger ages, so it was set to be flat for RCp. Inspection of proportions-at-age residuals suggested a systematic pattern change for the commercial catch proportions-at-age in the mid-1990s. Katherine Sosebee suggested two specific possibilities for the time of this change based on other information; a change from 1997 to 1998 was selected for distinguishing two commercial selectivity blocks based on a better AIC (where this criterion also clearly justified the split from the previous single block).

The list of sensitivities to RCp that are presented in this paper is given in Appendix Table B1.1.

Results

Appendix Table B1.2 lists estimates of primary parameters and management-related quantities for Georges' Bank/Gulf of Maine white hake for RCp and a series of sensitivities. Estimates of BRPs and current stock status estimates are summarized in Appendix Table B1.3. Additional runs, including the final run that was compared to the ASAP model are summarized in Appendix Table B1.4.

Appendix Figure B1.1 gives results for the RCp, while Appendix Figure B1.2 plots its fit to survey and commercial data. Appendix Figure B1.3 compares spawning biomass and recruitment trajectories for RCp and the different sensitivities. Appendix Figure B1.4 compares the stock-recruitment curves for RCp (Ricker), sensitivity 2a (Beverton-Holt) and sensitivity 2b (modified Ricker, with γ estimated). The commercial and survey selectivities for RCp and the sensitivities related to selectivities (4a/b/c/d) are plotted in Appendix Figure B1.5. Bubble plots of CAA residuals are compared for RCp, 4a (flat survey selectivity), 6a (sqrt(p)) and 6b (sqrt(p), flat survey selectivity). The fits to the survey and commercial CAA and CAL data for sensitivity 8c, for which CAA from pooled ALKs are excluded and replaced by CAL, are shown in Appendix Figure B1.6. The fits to the survey biomass indices for sensitivity 9a, in which the *RV Albatross/FRV Henry B. Bigelow* calibration factor is estimated, are plotted in Appendix Figure B1.7.

Discussion

1) The fits to the data do not suggest *M* values greater than 0.2. (Sensitivity 1)

2) The Ricker stock-recruitment form is favoured over Beverton-Holt, with the data suggesting a sharper peak than the standard Ricker form, though the evidence for preference in terms of improvements to the likelihood is not strong. (Sensitivity 2)
3) Fitting to aggregate abundance indices in terms of numbers, rather than biomass, results in higher current and pristine spawning biomass estimates, but current stock status relative to the MSY spawning biomass level is not greatly affected. If only the spring NEFSC survey data are used, this status is improved, with the reverse result if only the autumn survey data are used. (Sensitivity 3)
4) Investigation of alternative assumptions for selectivity functions show strong AIC support for a difference in the slopes of commercial and survey selectivities-at-age above age 6, with a preference for a near-flat commercial selectivity and strongly domed survey selectivities. The alternative sqrt(p) formulation for the distribution of the proportions-at-age residuals finds this same result, and suggests slightly improved current resource status relative to the MSY spawning biomass level than does the adjusted log-normal of RCp. Shifting the pre-1982 commercial selectivity towards a relatively larger catch of smaller hake has little impact on results. (Sensitivities 4 and 6)
5) When starting the assessment in 1963, the parameter which determines the initial age structure is poorly estimated, but this doesn't impact seriously on the estimates of biological reference points in terms of precision, with starting in 1950 instead also making little difference (note results falling well within CIs for the 1963 start in early years in Fig. 3a). In contrast, for a start in 1982, although *phi* becomes estimable with reasonable precision, the stock-recruitment relationship cannot be reasonably estimated. (Sensitivity 5)
6) Removable of an internally estimated stock-recruitment relationship results, through differences in the related shrinkage of recent estimates of recruitment, in lower estimates of current abundance. (Sensitivity 7)
7) Without inclusion of catch proportions-at-age data for years without direct ageing through use of an average ALK, the precision of the estimates of many quantities deteriorates substantially. However fitting to catch-at-length data for those years provides near unchanged results in terms of both these values and their precision. (Sensitivity 8).
8) Refining the *RV Albatross/FRV Henry B. Bigelow* calibration factor within the assessment leads to a slightly improved estimate of current stock status. The estimate of this factor decreases from 2.235 to 2.096, with an improvement in the associated standard error from 0.173 to 0.155. (Sensitivity 9)
9) The RCp assessment and a number of key sensitivities all suggest that at present the stock is not overfished and that overfishing is not occurring. Estimates of current status and of catches under 0.75 F_{MSY} are rather more optimistic when based on fitted stock-recruitment curves than on F40% MSY proxies. For the latter, starting the assessment in 1963 yields slightly more positive results than starting it in 1982. (Appendix Table B1.3)

Appendix Table B1.1: List of the sensitivities run. After each sub-heading, the RCp specifications are given in parenthesis.

1. Natural mortality (RCp: *M*=0.2)
   1a. *M*=0.4
   1b. *M* incr: *M* increasing linearly from 0.2 at age 5 to 0.4 at age 9
2. Stock-recruitment curve (RCp: Ricker)
   2a BH:Beverton-Holt stock-recruitment curve
   2b γ estimated: from the modified Ricker, eqn B2.4
3. Survey data (RCp: Fit to biomass, both surveys)
   3a Fit to numbers: for the survey indices
   3b Fit to Spring survey only: for both the index and CAA data
   3c Fit to Autumn survey only: for both the index and CAA data
4. Selectivities (RCp: flat comm. From age 6, domed survey)
   4a Flat survey selectivity: from age 6
   4b Pre-1982 comm sel shifted: shifted one year to the left
   4c Flat survey sel, domed comm. Sel: flat from age 6 for survey, free for commercial
   4d Domed survey and comm. Sel
5. Start year (RCp: start in 1963)
   5a Start in 1982
   5b Start in 1950
6. CAA error formulation (RCp: adjusted log-normal)
   6a sqrt(p)
   6b sqrt(p), flat survey selectivity
7. No internal stock-recruitment (RCp: internal stock-recruit)
   7a no SR
   7b no SR, start 1982
8. Excluding CAA from pooled ALK (RCp: include CAA from pooled ALK)
   8a Survey CAL for yrs with pooled ALK
   8b Surv and comm CAL for yrs with pooled ALK
   8c Exclude CAA from pooled ALK: not fitting to any CAL
9. Calibration refinement (RCp: calibration refinement not included)
   9a Bigelow calibration: Δlnq estimated (equation B2.33)

Appendix Table B1.2a: Results for RCp and some sensitivities. Mass units are '000 tons.

	RCp		1a		1b		2a		2b		3a		3b		3c	
			M =0.4		*M* incr		BH		γ estimated		Fit to Numbers		Fit to Spring survey only		Fit to Autumn survey only	
'-lnL:overall	-368.3		-365.3		-367.7		-367.1		-369.0		-362.0		-151.5		-280.9	
'-lnL:Survey	-34.3		-26.2		-28.5		-34.6		-34.2		-30.7		-6.9		-30.5	
'-lnL:CAAcom	-42.6		-46.4		-45.2		-42.6		-42.6		-43.4		-47.3		-48.5	
'-lnL:CAAsurv	-301.6		-301.6		-303.3		-301.3		-301.4		-300.4		-105.8		-214.1	
'-lnL:CALcom	-		-		-		-		-		-		-		-	
'-lnL:Catch	1.1		1.5		1.3		1.2		1.1		1.6		0.9		1.3	
'-lnL:CALsurv	-		-		-		-		-		-		-		-	
'-lnL:RecRes	9.0		7.4		7.9		10.2		8.1		10.9		7.7		10.8	
-lnL:calibration	-		-		-		-		-		-		-		-	
MaxGradient	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
h	1.21	(0.14)	0.62	(0.15)	0.74	(0.15)	0.78	(0.09)	1.26	(0.13)	0.81	(0.14)	1.30	(0.15)	1.24	(0.15)
γ	1.00	-	1.00	-	1.00	-	1.00	-	2.11	(0.50)	1.00	-	1.00	-	1.00	-
θ	0.57	(0.29)	0.57	(0.21)	0.56	(0.19)	0.28	(0.34)	0.77	(0.17)	0.25	(0.29)	0.77	(0.19)	0.52	(0.28)
ϕ	0.01	(4.07)	0.00	(1000)	0.00	(1000)	0.02	(1.65)	0.00	(1000)	0.03	(4.07)	0.00	(1000)	0.02	(1.81)
K^{sp}	69.13	(0.14)	68.91	(0.19)	66.39	(0.17)	128.17	(0.20)	55.08	(0.17)	120.65	(0.14)	71.01	(0.14)	64.82	(0.15)
$B^{sp}{}_{2011}$	25.34	(0.17)	37.17	(0.18)	32.38	(0.18)	24.77	(0.17)	25.25	(0.18)	29.78	(0.17)	33.99	(0.23)	22.45	(0.19)
$B^{sp}{}_{2011}/K^{sp}$	0.37	(0.21)	0.54	(0.24)	0.49	(0.22)	0.19	(0.26)	0.46	(0.21)	0.25	(0.21)	0.48	(0.26)	0.35	(0.23)
$B^{sp}{}_{MSY}$	30.43	(0.10)	32.35	(0.13)	31.57	(0.12)	42.98	(0.16)	29.38	(0.13)	39.44	(0.10)	31.05	(0.11)	28.53	(0.10)
$MSYL^{sp}$	0.44	(0.11)	0.47	(0.16)	0.48	(0.13)	0.34	(0.07)	0.53	(0.24)	0.33	(0.11)	0.44	(0.12)	0.44	(0.11)
$B^{sp}{}_{2011}/B^{sp}{}_{MSY}$	0.83	(0.18)	1.15	(0.18)	1.03	(0.18)	0.58	(0.23)	0.86	(0.20)	0.76	(0.18)	1.09	(0.22)	0.79	(0.19)
MSY	7.75	(0.10)	8.37	(0.13)	8.39	(0.12)	7.82	(0.15)	8.57	(0.13)	7.60	(0.10)	8.44	(0.10)	7.41	(0.10)
F_{MSY}	0.30	-	0.41	-	0.35	-	0.21	-	0.35	-	0.22	-	0.33	-	0.31	-
spring_q	1.16	(0.06)	0.54	(0.07)	0.86	(0.07)	1.16	(0.06)	1.16	(0.06)	1.06	(0.06)	1.10	(0.06)	-	
autumn_q	1.96	(0.05)	0.97	(0.07)	1.42	(0.07)	1.97	(0.05)	1.97	(0.05)	1.71	(0.05)	-		2.04	(0.05)
spring_σ_{Add}	0.16	(0.32)	0.17	(0.32)	0.16	(0.32)	0.16	(0.32)	0.16	(0.32)	0.13	(0.31)	0.20	(0.29)	-	
autumn_σ_{Add}	0.06	(0.48)	0.10	(0.40)	0.09	(0.41)	0.05	(0.49)	0.05	(0.49)	0.14	(0.30)	-		0.07	(0.33)

Appendix Table B.2b: Results for RCp and some sensitivities. Mass units are '000 tons.

	RCp		4a		4b		4c		4d		5a		5b	
			Flat survey selectivity		Pre-1982 comm sel shifted		Flat survey sel, domed comm sel		Domed survey and comm sel		start in 1982		start in 1950	
'-lnL:overall	-368.3		-341.1		-366.6		-355.4		-369.6		-191.8		-369.6	
'-lnL:Survey	-34.3		-37.2		-33.9		-37.7		-29.8		-22.7		-33.9	
'-lnL:CAAcom	-42.6		-33.8		-42.7		-40.4		-47.2		-45.5		-42.2	
'-lnL:CAAsurv	-301.6		-287.3		-299.8		-295.7		-301.2		-131.0		-304.4	
'-lnL:CALcom	-		-		-		-		-		-		-	
'-lnL:Catch	1.1		5.9		1.0		6.2		1.4		1.3		1.1	
'-lnL:CALsurv	-		-		-		-		-		-		-	
'-lnL:RecRes	9.0		11.4		8.7		12.1		7.3		6.0		9.9	
-lnL:calibration	-		-		-		-		-		-		-	
MaxGradient	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000	
h	1.21	(0.14)	1.47	(0.17)	1.19	(0.14)	1.44	(0.16)	0.98	(0.19)	0.86	(0.26)	1.25	(0.14)
γ	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-	1.00	-
θ	0.57	(0.29)	0.19	(0.36)	0.57	(0.27)	0.22	(0.34)	0.61	(0.16)	0.04	(8.32)	0.45	(1.17)
ϕ	0.01	(4.07)	0.26	(0.19)	0.01	(2.94)	0.50	(0.32)	0.00	(1000)	0.25	(0.18)	0.53	(0.99)
K^{sp}	69.13	(0.14)	63.19	(0.31)	73.12	(0.14)	58.73	(0.28)	97.24	(0.24)	730.11	(8.27)	66.82	(0.12)
B^{sp}_{2011}	25.34	(0.17)	16.06	(0.18)	26.01	(0.17)	15.47	(0.17)	33.67	(0.23)	22.18	(0.20)	25.74	(0.17)
B^{sp}_{2011}/K^{sp}	0.37	(0.21)	0.25	(0.37)	0.36	(0.21)	0.26	(0.34)	0.35	(0.21)	0.03	(8.30)	0.39	(0.18)
B^{sp}_{MSY}	30.43	(0.10)	27.46	(0.23)	32.26	(0.10)	27.28	(0.25)	42.79	(0.18)	333.38	(8.07)	29.33	(0.10)
$MSYL^{sp}$	0.44	(0.11)	0.43	(0.11)	0.44	(0.10)	0.46	(0.17)	0.44	(0.15)	0.46	(0.22)	0.44	(0.11)
$B^{sp}_{2011}/B^{sp}_{MSY}$	0.83	(0.18)	0.58	(0.29)	0.81	(0.17)	0.57	(0.32)	0.79	(0.19)	0.07	(8.10)	0.88	(0.17)
MSY	7.75	(0.10)	8.40	(0.23)	8.08	(0.10)	8.13	(0.21)	8.87	(0.13)	63.64	(8.07)	7.63	(0.09)
F_{MSY}	0.30	-	0.41	-	0.29	-	0.66	-	0.29	-	0.22	-	0.30	-
spring_q	1.16	(0.06)	1.24	(0.05)	1.15	(0.06)	1.30	(0.05)	0.98	(0.12)	1.14	(0.07)	1.16	(0.06)
autumn_q	1.96	(0.05)	2.17	(0.05)	1.96	(0.05)	2.28	(0.04)	1.65	(0.12)	2.09	(0.06)	1.97	(0.05)
spring_σ_{Add}	0.16	(0.32)	0.16	(0.32)	0.16	(0.32)	0.17	(0.32)	0.16	(0.32)	0.14	(0.39)	0.16	(0.32)
autumn_σ_{Add}	0.06	(0.48)	0.04	(0.54)	0.06	(0.47)	0.04	(0.55)	0.09	(0.46)	0.05	(0.82)	0.06	(0.48)

Appendix Table B1.2c: Results for RCp and some sensitivities. Note that for 7a, the BRP are estimated externally to the assessment (see Appendix B2, section B2.5). For sensitivity 9a (Bigelow calibration), the first two survey *q*'s (and associated CVs) are for the *Albatross*, followed by those for the *Bigelow*. Mass units are '000 tons.

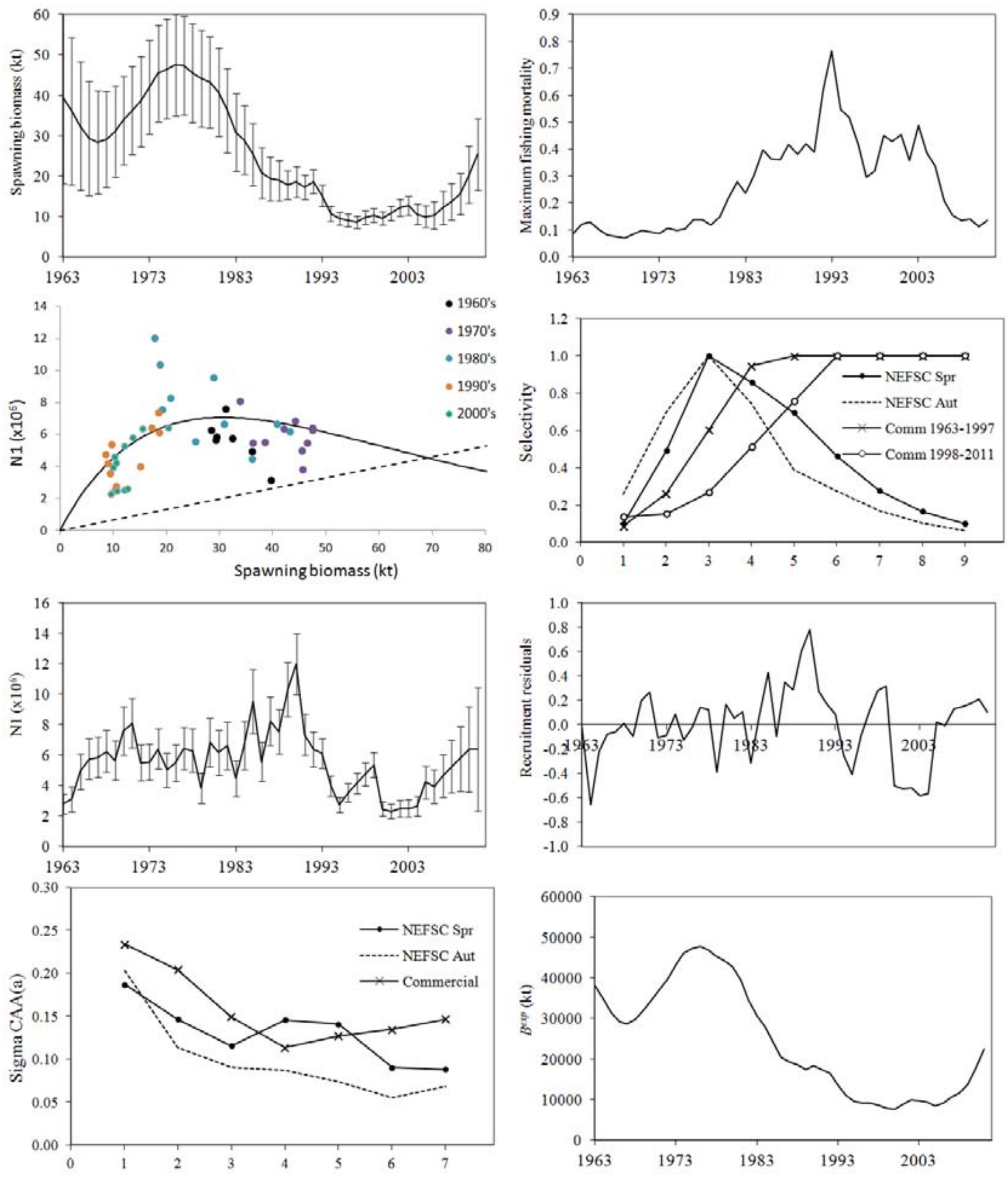
	RCp		6a		6b		7a		7b		8a		8b		8c		9a			
			sqrt(p)		sqrt(p), flat survey selectivity		no SR		no SR, start 1982		Surv CAL for yrs with pooled ALK		Surv and comm CAL for yrs with pooled ALK		Exclude CAA from pooled ALK		Bigelow calibration			
'-lnL:overall	-368.3		-1905		-1880		-376.3		-197.4		-79.6		-64.5		-158.9		-368.6			
'-lnL:Survey	-34.3		-33.1		-36.6		-36.5		-23.6		-35.0		-35.0		-38.3		-34.8			
'-lnL:CAAcom	-42.6		-327.9		-317.1		-44.1		-46.5		-24.2		-24.8		-22.7		-42.7			
'-lnL:CAAsurv	-301.6		-1556		-1545		-298.5		-129.5		-98.6		-96.5		-108.1		-301.7			
'-lnL:CALcom	-		-		-		-		-		-		13.7		-		-			
'-lnL:Catch	1.1		1.4		4.7		1.5		1.5		1.1		1.2		1.8		1.2			
'-lnL:CALsurv	-		-		-		-		-		66.9		66.6		-		-			
'-lnL:RecRes	9.0		11.0		13.6		1.3		0.7		10.2		10.2		8.4		9.0			
-lnL:calibration	-		-		-		-		-		-		-		-		0.3			
MaxGradient	0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000		0.0000			
h	1.21	(0.14)	1.39	(0.13)	1.59	(0.16)	-		-		1.27	(0.16)	1.29	(0.15)	1.05	(0.21)	1.22	(0.14)		
γ	1.00	-	1.00	-	1.00	-	-		-		1.00	-	1.00	-	1.00	-	1.00	-		
θ	0.57	(0.29)	0.59	(0.30)	0.23	(0.28)	0.50	(0.13)	-		0.60	(0.20)	0.57	(0.58)	0.11	(0.80)	0.57	(0.29)		
ϕ	0.01	(4.07)	0.02	(2.48)	0.28	(0.22)	0.02	(1.71)	0.25	(0.10)	0.00	(1000)	0.01	(11.75)	0.38	(0.93)	0.01	(3.81)		
K^{sp}	69.13	(0.14)	63.76	(0.13)	53.93	(0.22)	68.32	(0.13)	-		65.64	(0.15)	64.19	(0.15)	95.32	(0.47)	68.82	(0.14)		
B^{sp}_{2011}	25.34	(0.17)	25.47	(0.18)	16.80	(0.18)	21.31	(0.17)	19.17	(0.09)	23.03	(0.19)	22.74	(0.19)	19.63	(0.19)	25.97	(0.17)		
B^{sp}_{2011}/K^{sp}	0.37	(0.21)	0.40	(0.19)	0.31	(0.29)	0.31	(0.13)	-		0.35	(0.21)	0.35	(0.23)	0.21	(0.54)	0.38	(0.21)		
B^{sp}_{MSY}	30.43	(0.10)	27.66	(0.10)	23.24	(0.16)	29.49	(0.09)	-		28.80	(0.11)	28.14	(0.11)	42.70	(0.35)	30.28	(0.10)		
$MSYL^{sp}$	0.44	(0.11)	0.43	(0.10)	0.43	(0.10)	0.43	(0.09)	-		0.44	(0.14)	0.44	(0.12)	0.45	(0.17)	0.44	(0.11)		
$B^{sp}_{2011}/B^{sp}_{MSY}$	0.83	(0.18)	0.92	(0.17)	0.72	(0.23)	0.72	(0.09)	-		0.80	(0.20)	0.81	(0.20)	0.46	(0.44)	0.86	(0.18)		
MSY	7.75	(0.10)	8.01	(0.10)	7.66	(0.15)	7.50	(0.09)	-		7.46	(0.10)	7.53	(0.10)	9.45	(0.35)	7.76	(0.10)		
F_{MSY}	0.30	-	0.36	-	0.46	-	0.30		-		0.30	-	0.32	-	0.25	-	0.24	-		
spring_q	1.16	(0.06)	1.25	(0.06)	1.35	(0.05)	1.20	(0.06)	1.18	(0.07)	1.13	(0.07)	1.13	(0.07)	1.30	(0.08)	1.17	(0.06)	2.45	(0.10)
autumn_q	1.96	(0.05)	2.06	(0.06)	2.27	(0.05)	2.05	(0.05)	2.17	(0.06)	1.93	(0.07)	1.93	(0.07)	2.13	(0.07)	2.01	(0.05)	4.21	(0.09)
spring_σ_{Add}	0.16	(0.32)	0.16	(0.32)	0.16	(0.32)	0.16	(0.32)	0.14	(0.39)	0.18	(0.08)	0.16	(0.33)	0.18	(0.32)	0.16	(0.32)		
autumn_σ_{Add}	0.06	(0.48)	0.06	(0.47)	0.04	(0.52)	0.04	(0.53)	0.03	(0.95)	0.16	(0.33)	0.05	(0.52)	0.03	(0.70)	0.05	(0.50)		

Appendix Table B1.3: BRPs for RCp and some sensitivities. Mass units are tons.

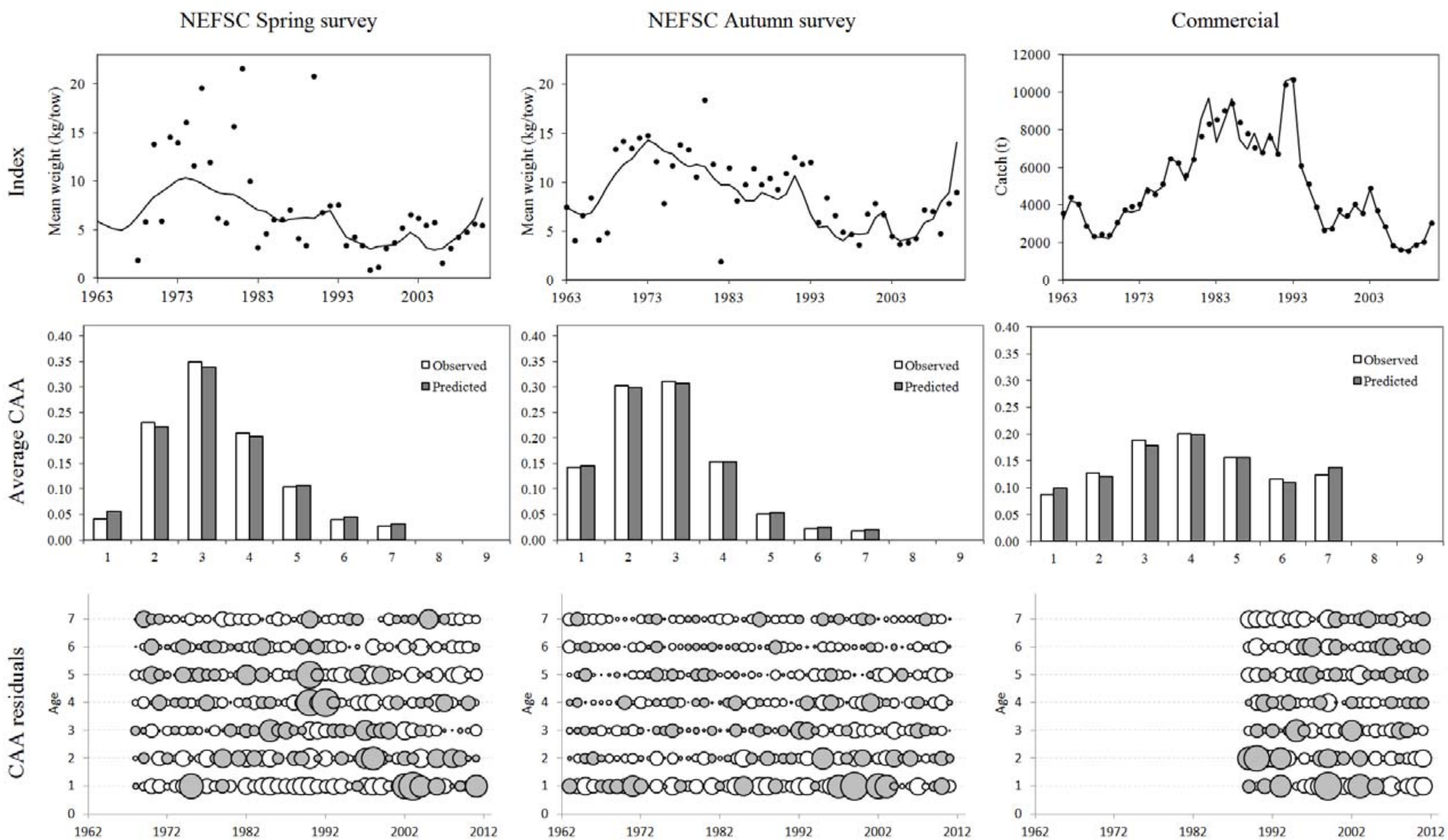
		RCp	2a	7a	7b
			BH	no SR	no SR, start 1982
	Start year	1963	1963	1963	1982
	SR relationship	Ricker	Beverton-Holt	None (Ricker external)	
SR BRPs	$B^{sp}_{2011}/B^{sp}_{MSY}$	0.83	0.58	0.72	
	F_{2011}/F_{MSY}	0.45	0.67	0.54	
	MSY	7.75	7.82	7.50	
	$C_{2012}(0.75F_{MSY})$	6986	4883	5786	
	overfished	No	No	No	
	overfishing	No	No	No	
*F*40% BRPs	$B^{sp}_{2011}/B^{sp}_{MSY}$	0.71	0.69	0.61	0.57
	F_{2011}/F_{MSY}	0.75	0.77	0.90	1.01
	MSY	5.73	5.74	5.57	5.40
	$C_{2012}(0.75F_{MSY})$	4394	4299	3650	3274
	overfished	No	No	No	No
	overfishing	No	No	No	Yes

Appendix Table B1.4 Exploration of the SCAA with the final data (RCeven_newer).

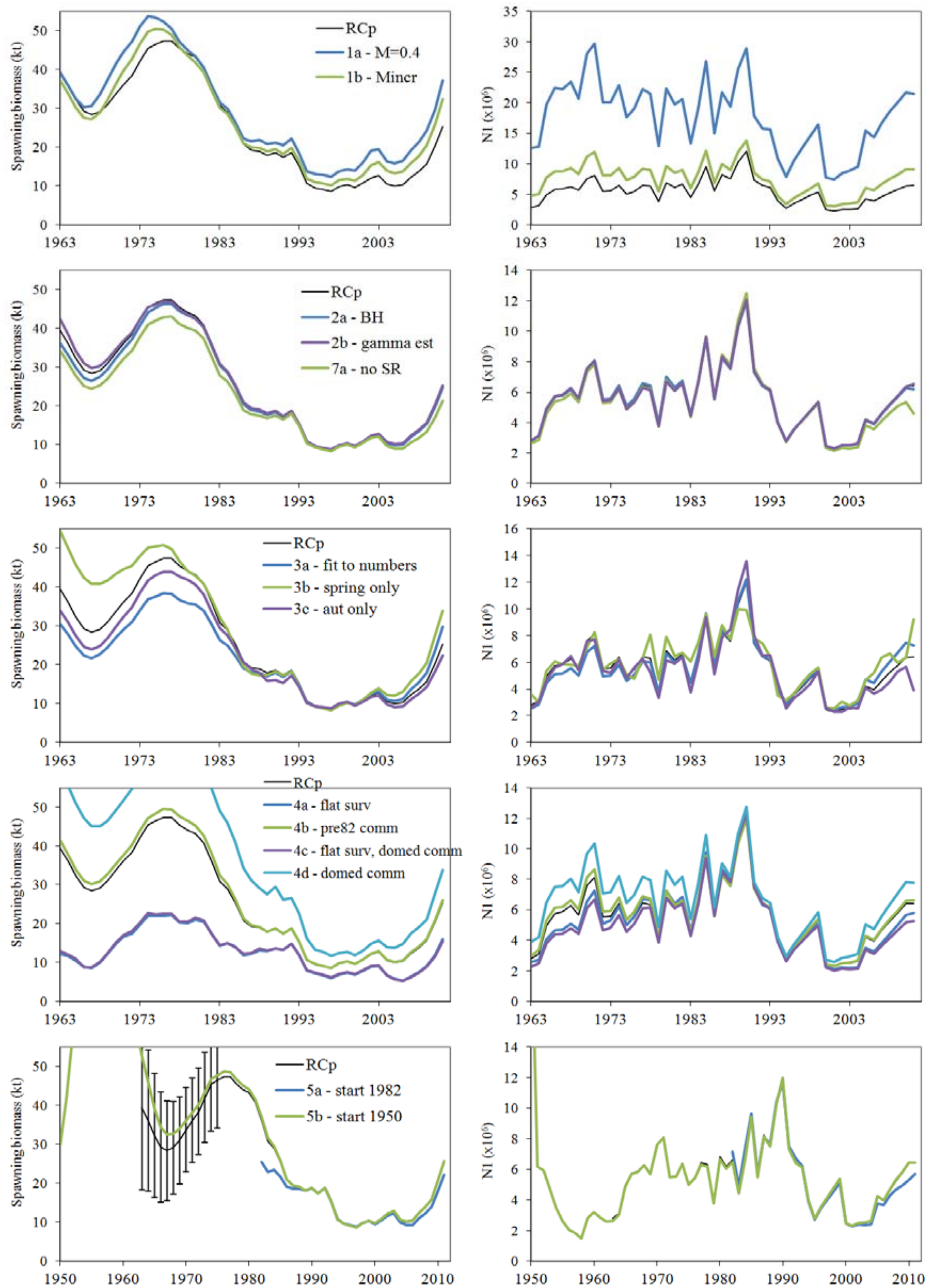
				2a	2b	5a	8a	9a	Ka	Kb	Kc
	RCnew	RCeven_newer	RCeven_newer	BH	no SR	start in 1950	CAL for yr with pooled ALK	Estimate calibration ratio	BH, ϕ=0.4	BH, $N_{y0,m}/4$	BH, ASAP Bsp
	Fit to B	Fit to B	Fit to N	Fit to N	Fit to N	Fit to N	Fit to N	Fit to N	Fit to N	Fit to N	Fit to N
'-lnL:overall	-344.3	-339.6	-348.2	-347.7	-356.7	-346.5	-117.9	-348.7	-312.7	-330.4	-293.3
'-lnL:Survey	-33.6	-34.6	-39.5	-39.7	-41.4	-39.5	-40.2	-40.1	-37.5	-40.9	-41.5
'-lnL:CAAcom	-41.6	-41.0	-43.6	-43.5	-44.6	-43.6	-44.6	-43.6	-37.8	-37.5	-47.4
'-lnL:CAAsurv	-280.6	-275.2	-275.4	-275.3	-272.7	-275.8	-107.9	-275.8	-248.1	-263.1	-242.5
'-lnL:CALcom	-	-	-	-	-	-	7.1	-	-	-	0.0
'-lnL:Catch	0.4	0.3	0.3	0.3	0.3	0.2	0.3	0.3	1.2	0.6	26.5
'-lnL:CALsurv	-	-	-	-	-	-	56.0	-	-	-	0.0
'-lnL:RecRes	11.1	10.9	10.0	10.6	1.7	12.0	11.5	10.0	9.6	10.5	11.5
-lnL:calibration	-	-	-	-	-	-	-	0.4	-	-	-
MaxGradient	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1	0.0385
h	1.26 (0.15)	1.21 (0.15)	1.36 (0.16)	0.82 (0.10)	-	0.80 (0.11)	1.43 (0.15)	1.37 (0.16)	0.76 (0.08)	0.86 (0.11)	0.73 (0.09)
γ	1.00 -	1.00 -	1.00 -	1.00 -	-	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -
θ	0.44 (0.28)	0.44 (0.29)	0.48 (0.31)	0.23 (0.36)	-	0.04 (14.28)	1.00 (0.28)	0.48 (0.31)	0.05 (0.36)	0.18 (0.24)	0.04 (0.55)
ϕ	0.04 (0.95)	0.04 (0.99)	0.03 (1.24)	0.04 (0.93)	0.05 (0.78)	0.96 (13.73)	-0.06 -(1)	0.03 (1.20)	0.40 -	-0.49 (0.00)	0.26 (0.08)
K^{sp}	69.63 (0.16)	76.30 (0.16)	70.12 (0.15)	138.39 (0.21)	-	138.85 (0.24)	68.19 (0.13)	69.85 (0.15)	206.46 (0.33)	118.50 (0.17)	253.59 (0.55)
B^{sp}_{2011}	25.83 (0.16)	25.36 (0.16)	35.57 (0.14)	35.35 (0.14)	30.69 (0.14)	34.89 (0.14)	34.04 (0.14)	36.57 (0.14)	35.62 (0.14)	34.78 (0.13)	25.74 (0.00)
B^{sp}_{2011}/K^{sp}	0.37 (0.23)	0.33 (0.23)	0.51 (0.20)	0.26 (0.26)	-	0.25 (0.28)	0.50 (0.18)	0.52 (0.20)	0.17 (0.37)	0.29 (0.22)	0.10 (0.55)
B^{sp}_{MSY}	28.70 (0.11)	31.57 (0.12)	28.66 (0.11)	39.03 (0.16)	-	39.74 (0.18)	27.67 (0.10)	28.53 (0.11)	61.09 (0.28)	32.19 (0.13)	76.94 (0.48)
$MSYL^{sp}$	0.41 (0.14)	0.41 (0.14)	0.41 (0.13)	0.28 (0.09)	-	0.29 (0.10)	0.41 (0.13)	0.41 (0.13)	0.30 (0.08)	0.27 (0.10)	0.30 (0.08)
$B^{sp}_{2011}/B^{sp}_{MSY}$	0.90 (0.19)	0.80 (0.19)	1.24 (0.16)	0.91 (0.21)	-	0.88 (0.23)	1.23 (0.16)	1.28 (0.16)	0.58 (0.32)	1.08 (0.19)	0.33 (0.48)
MSY	7.62 (0.10)	8.07 (0.10)	8.12 (0.09)	8.10 (0.15)	-	8.01 (0.17)	8.30 (0.09)	8.16 (0.09)	11.55 (0.27)	7.16 (0.12)	13.74 (0.48)
F_{MSY}	0.30 -	0.29 -	0.32 -	0.23 -	-	0.22 -	0.35 -	0.33 -	0.21 -	0.24 -	0.20 -
spring_q	1.06 (0.05)	1.08 (0.05)	1.13 (0.04)	1.13 (0.04)	1.16 (0.04)	1.14 (0.04)	1.14 (0.05)	1.13 (0.04)	1.13 (0.04)	1.15 (0.05)	1.24 (0.03)
autumn_q	1.81 (0.05)	1.87 (0.04)	1.63 (0.04)	1.63 (0.04)	1.67 (0.04)	1.63 (0.04)	1.65 (0.05)	1.63 (0.04)	1.64 (0.04)	1.64 (0.04)	1.84 (0.03)
spring_σ_{Add}	0.16 (0.32)	0.18 (0.28)	0.16 (0.26)	0.16 (0.26)	0.16 (0.27)	0.16 (0.26)	0.15 (0.27)	0.16 (0.26)	0.15 (0.27)	0.16 (0.26)	0.15 (0.26)
autumn_σ_{Add}	0.06 (0.46)	0.10 (0.30)	0.11 (0.27)	0.11 (0.27)	0.10 (0.27)	0.11 (0.27)	0.10 (0.27)	0.10 (0.27)	0.12 (0.26)	0.10 (0.27)	0.10 (0.26)
Calibration Ratio	**2.09 (0.10)**	**2.09 (0.10)**	**2.24 (0.08)**	**2.24 (0.08)**	**2.24 (0.08)**	**2.24 (0.08)**	**2.24 (0.08)**	2.08 (0.07)	**2.24 (0.08)**	**2.24 (0.08)**	**2.24 (0.08)**



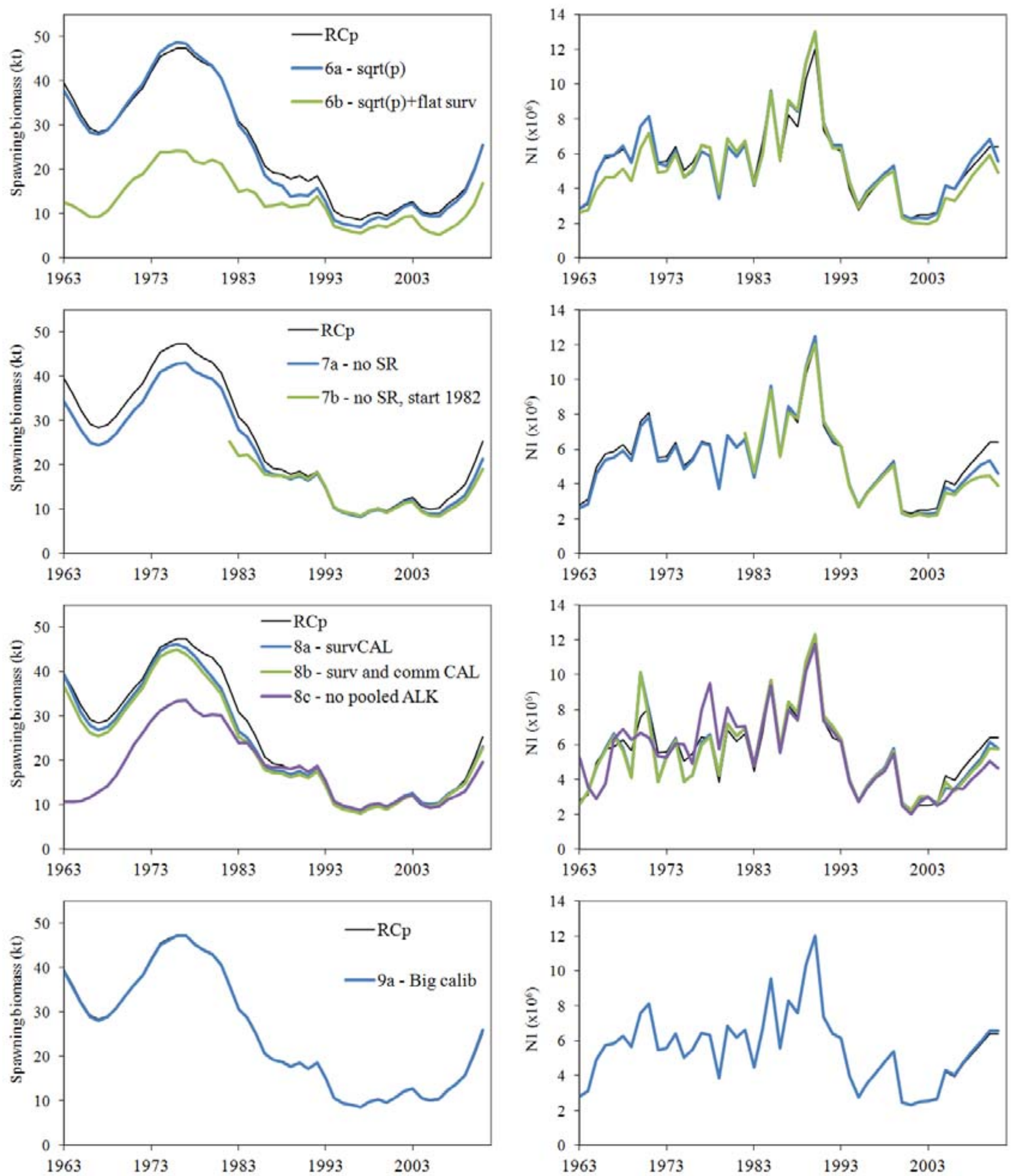
Appendix Figure B1.1: Results for the RCp Georges Bank/Gulf of Maine white hake assessment.



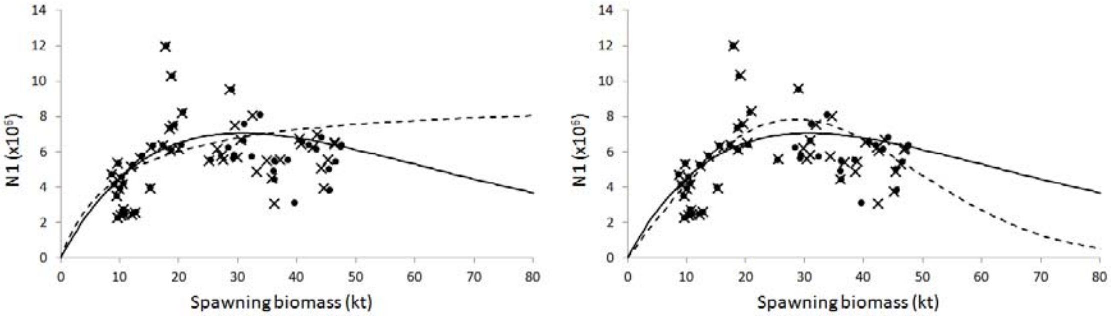
Appendix Figure B1.2: Fit of RCp to the survey and commercial data



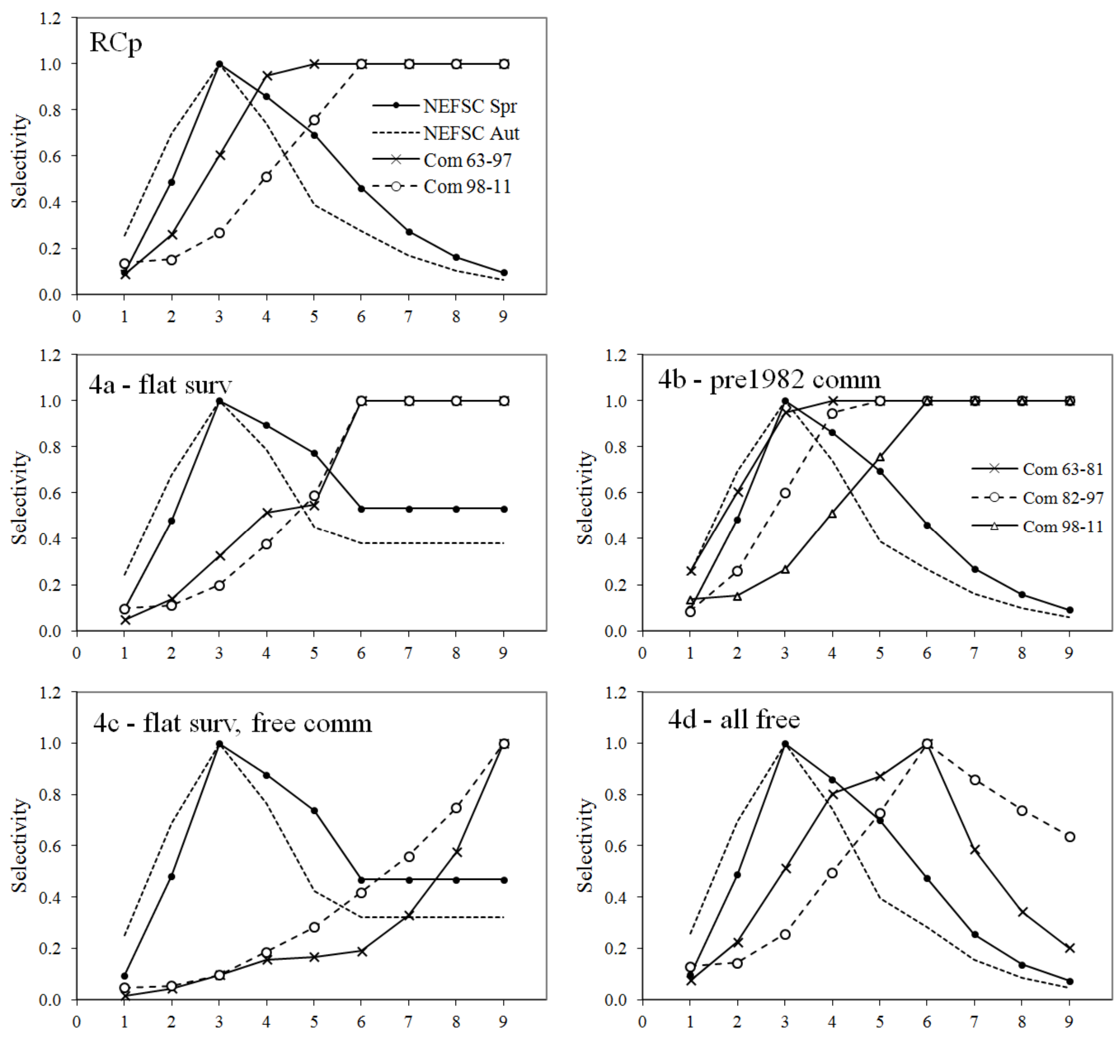
Appendix Figure B1.3a: Spawning biomass and recruitment trajectories for RCp and some sensitivities. The 95% CIs shown in the bottom left plot are for RCp.



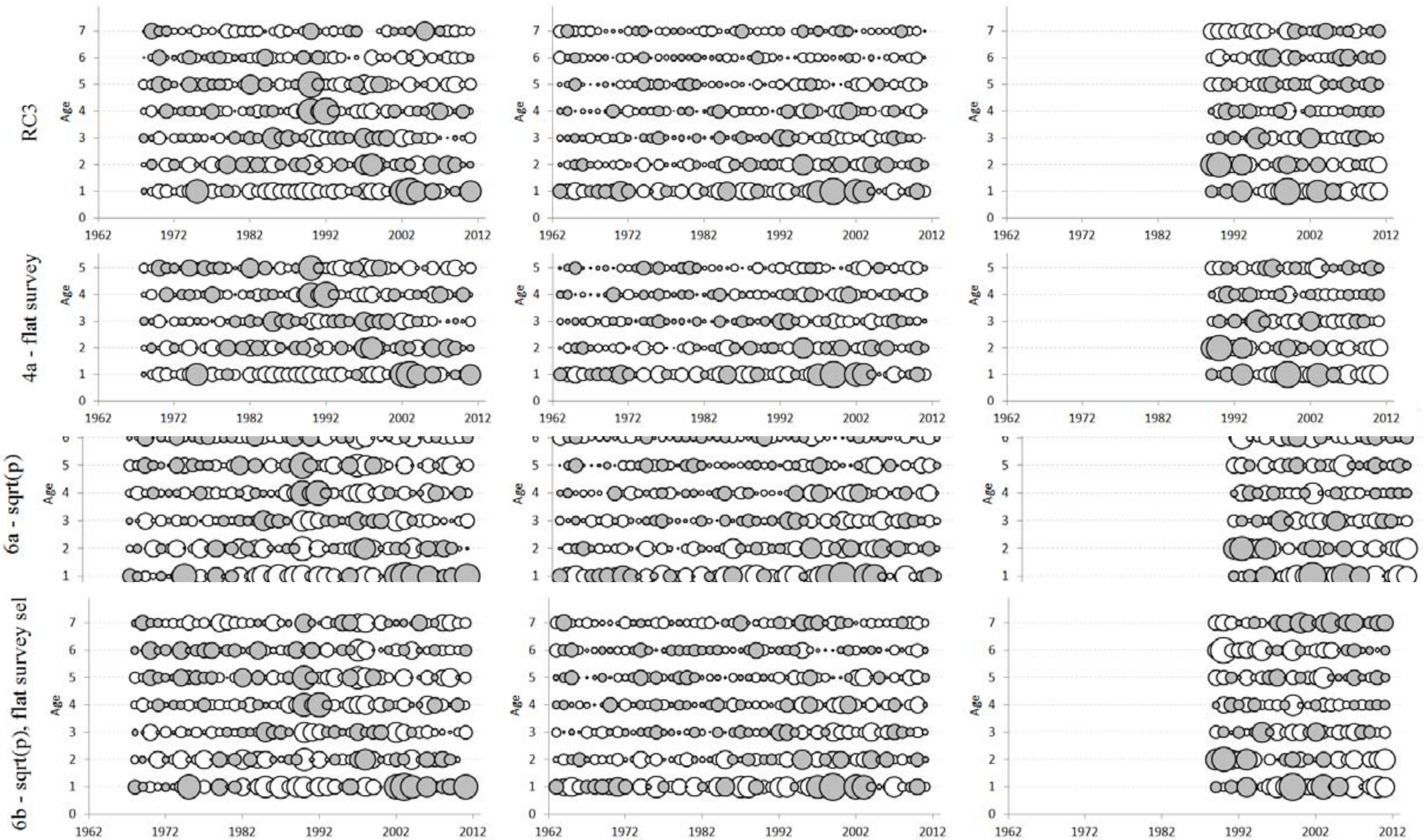
Appendix Figure B1.3b: Spawning biomass and recruitment trajectories for RCp and some sensitivities.



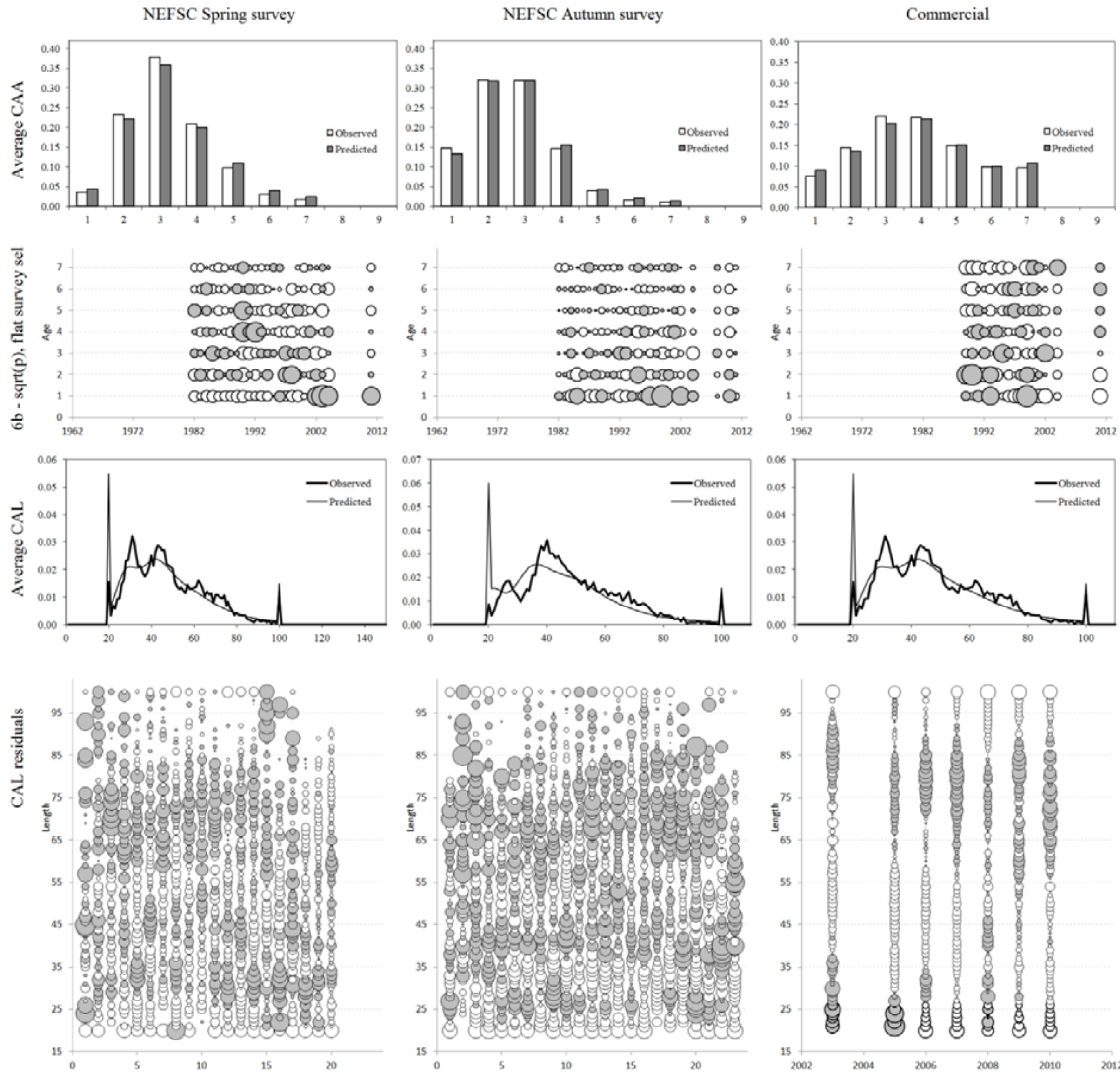
Appendix Figure B1.4: Stock-recruitment curve and estimated recruitment for RCp (full line and solid dots) and 2a (Beverton-Holt) (dashed line and crosses) for the left-hand plot and 2b (γ estimated) (dashed line and crosses) for the right-hand plot. Note that that N1 values for year *y* are associated with spawning biomass values for the previous year.



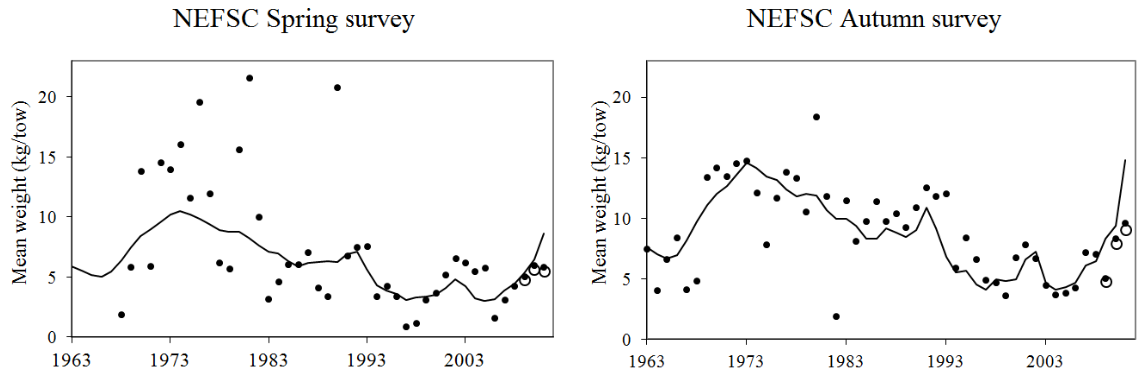
Appendix Figure B1.5: Commercial and survey selectivities for RCp and some sensitivities.



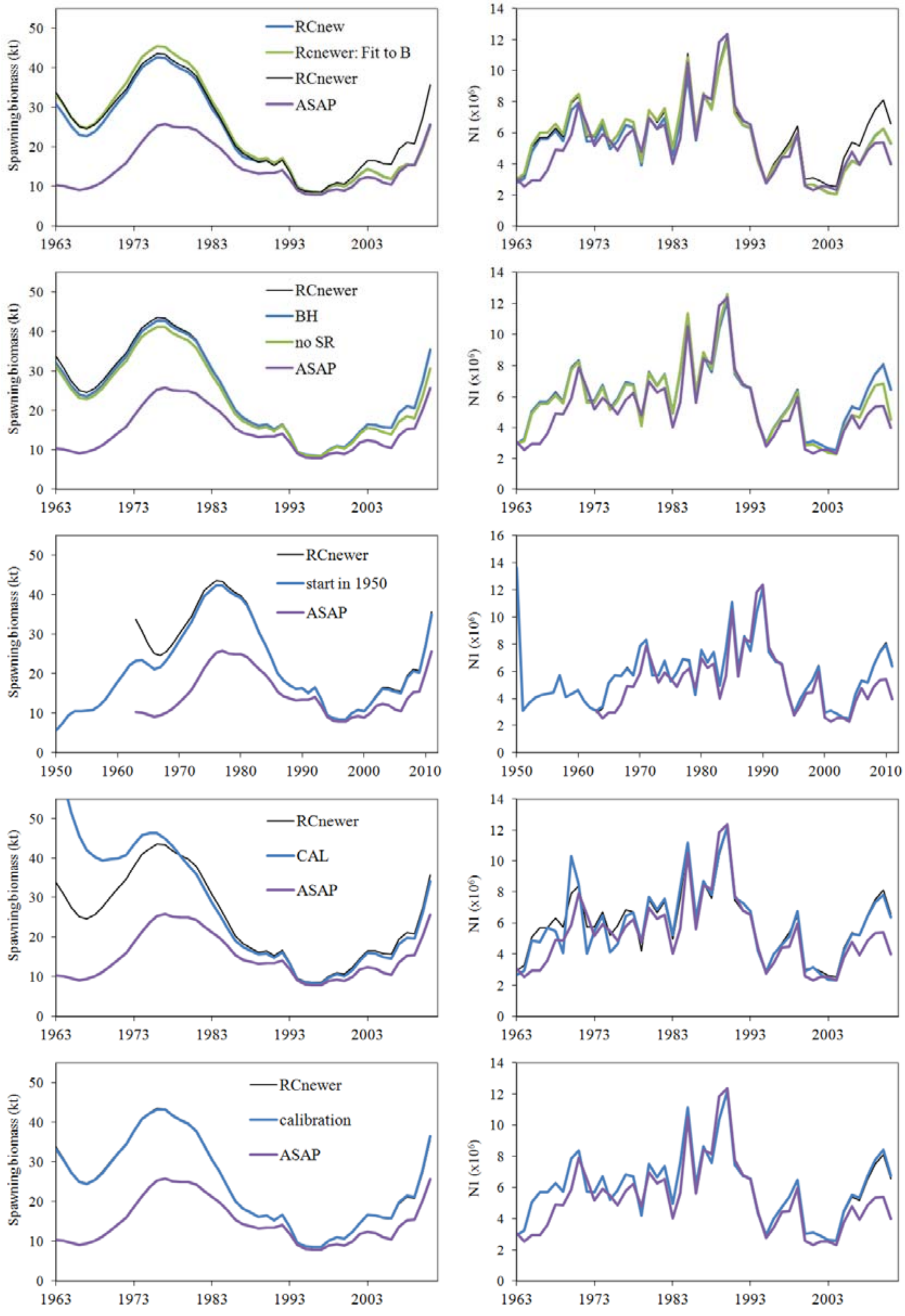
Appendix Figure B1.6: CAA standardised residuals for RCp and some sensitivities.



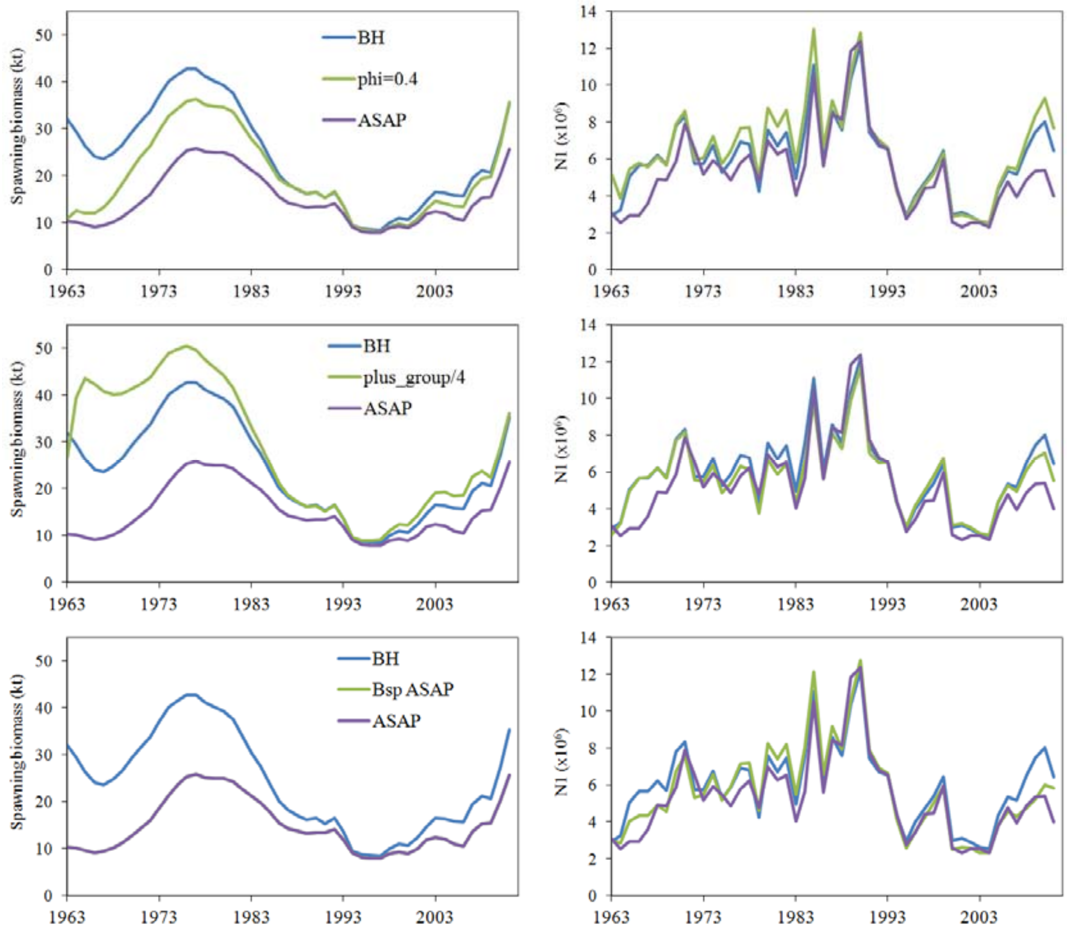
Appendix Figure B1.7: Fit to CAA and CAL for sensitivity 8c.



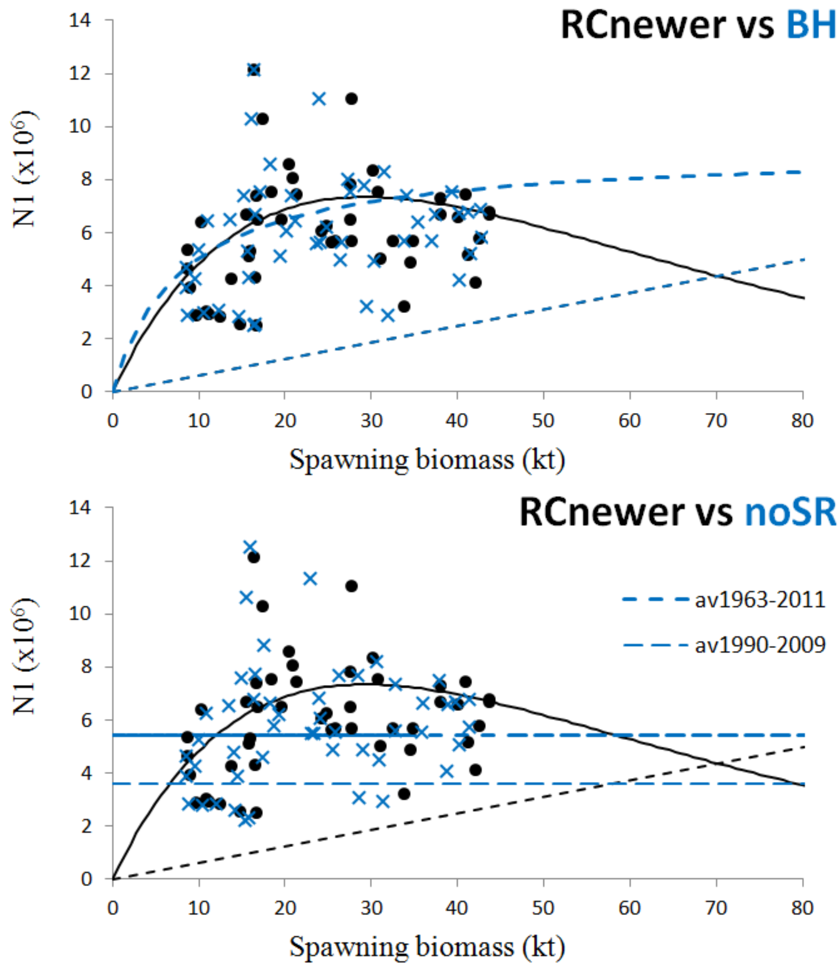
Appendix Figure B1.8: Fit to NEFSC surveys adjusted for the calibration refinement. Open circles are the surveys with the existing calibration factor.



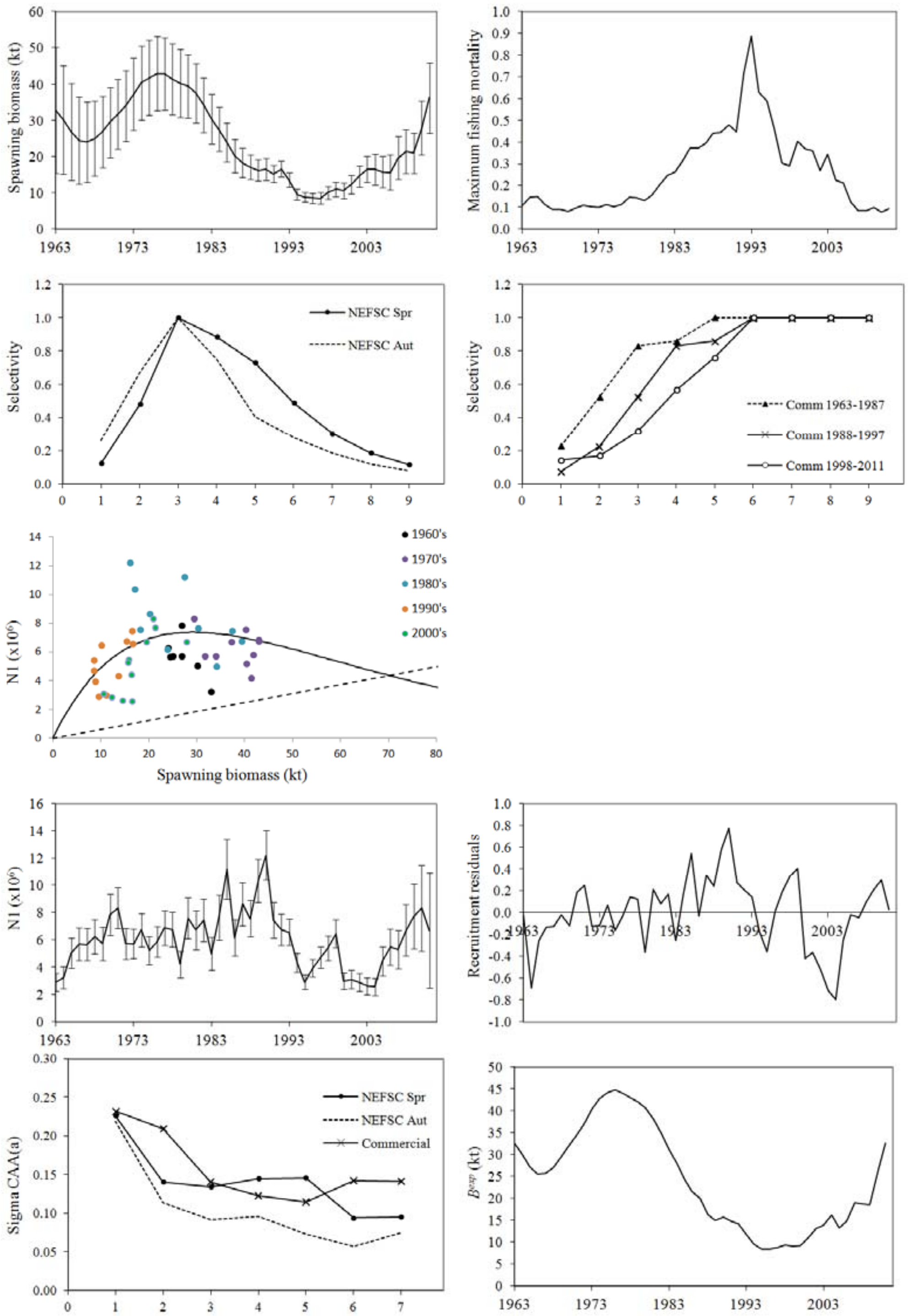
Appendix Figure B1.9a: Spawning biomass and recruitment trajectories for EvenNewerRCp and some sensitivities.



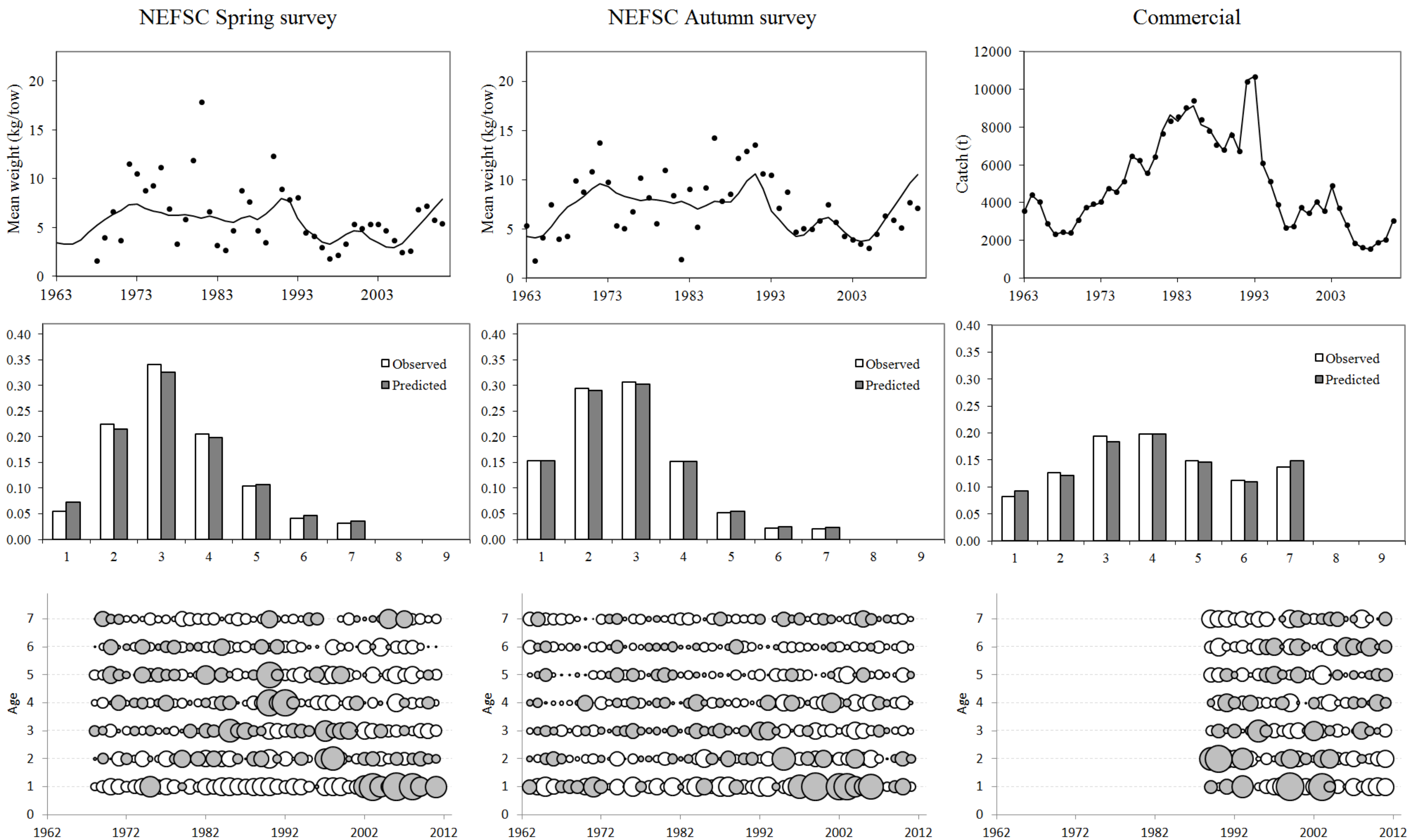
Appendix Figure B1.9b: Spawning biomass and recruitment trajectories for EvenNewerRCp and some sensitivities and a version of the ASAP.



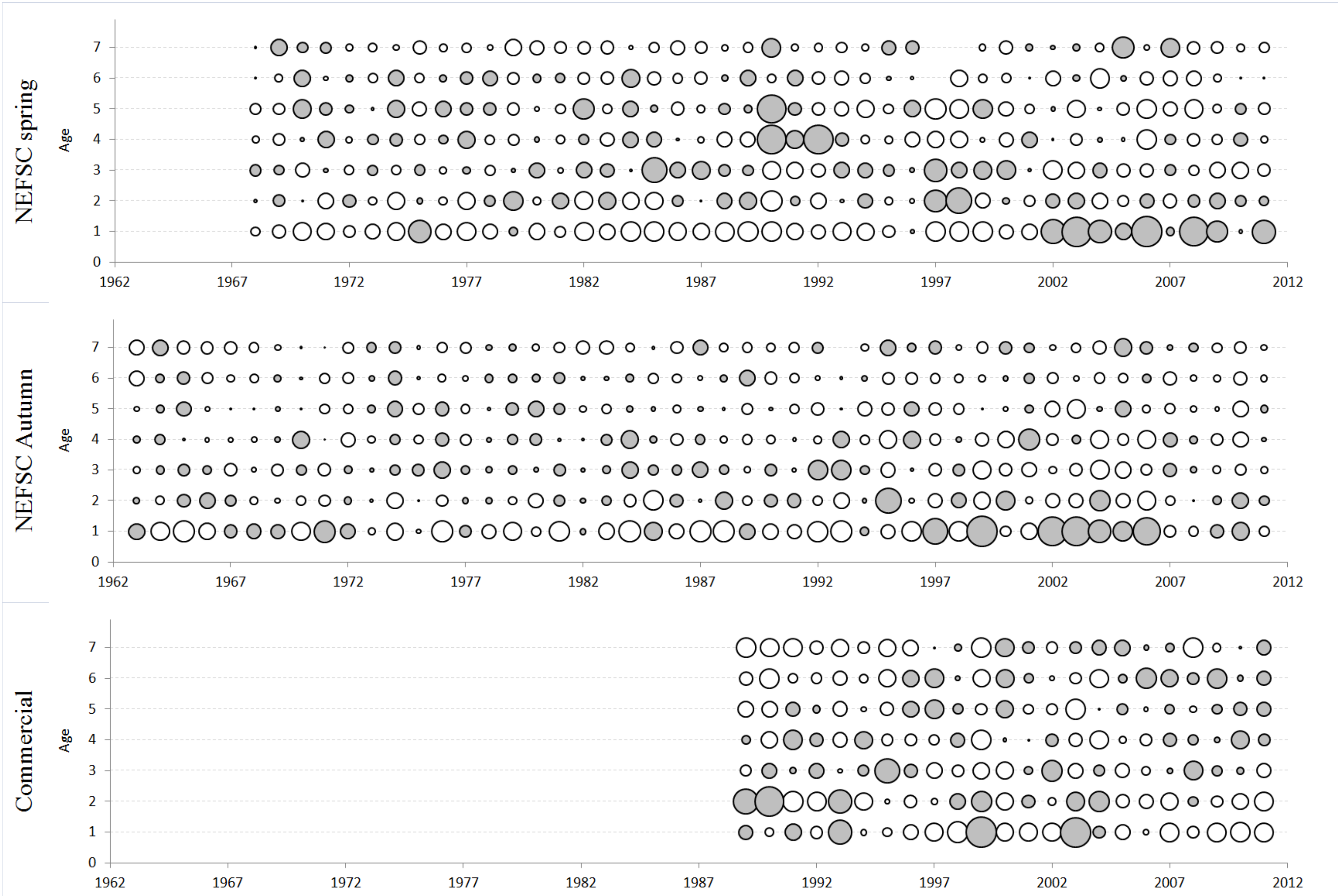
Appendix Figure B1.10. Spawner-recruit plots from RCNewer to BH and noSR



Appendix Figure B1.11: Results for the RCpEvenNewer Georges Bank/Gulf of Maine white hake assessment.



Appendix Figure B1.12a: Fit of RCpEvenNewer to the survey and commercial data



Appendix Figure B1.12b: Fit of RCpEvenNewer to the survey and commercial data

Appendix B2

Algebraic details of the Statistical Catch-at-Age Model

The text following sets out the equations and other general specifications of the Statistical Catch-at-Age (SCAA) assessment model applied to white hake, followed by details of the contributions to the (penalised) log-likelihood function from the different sources of data available and assumptions concerning the stock-recruitment relationship. Quasi-Newton minimization is applied to minimize the total negative log-likelihood function to estimate parameter values (the package AD Model Builder[TM], Otter Research, Ltd is used for this purpose).

Where options are provided under a particular section, the section concludes with a statement in **bold** as to which option was selected for the provisional Reference Case (RCp) run selected.

B2.1. Population dynamics

B2.1.1 Numbers-at-age

The resource dynamics are modelled by the following set of population dynamics equations:

$$N_{y+1,1} = R_{y+1} \quad \text{(B2.1)}$$

$$N_{y+1,a+1} = N_{y,a} e^{-Z_{y,a}} \qquad \text{for } 1 \le a \le m-2 \quad \text{(B2.2)}$$

$$N_{y+1,m} = N_{y,m-1} e^{-Z_{y,m-1}} + N_{y,m} e^{-Z_{y,m}} \quad \text{(B2.3)}$$

where

$N_{y,a}$ is the number of fish of age *a* at the start of year *y*,

R_y is the recruitment (number of 1-year-old fish) at the start of year *y*,

m is the maximum age considered (taken to be a plus-group).

$Z_{y,a} = F_y S_{y,a} + M_a$ is the total mortality in year *y* on fish of age *a*, where

M_a denotes the natural mortality rate for fish of age *a*,

F_y is the fishing mortality of a fully selected age class in year *y*, and

$S_{y,a}$ is the commercial selectivity at age *a* for year *y*.

B2.1.2. Recruitment

The number of recruits (i.e. new 1-year olds) at the start of year *y* is assumed to be related to the spawning stock size (i.e. the biomass of mature fish) by either a modified Ricker or a Beverton-Holt stock-recruitment relationship, allowing for annual fluctuation about the deterministic relationship.

For the modified Ricker:

$$R_y = \alpha B^{\text{sp}}_{y-1} \exp\left[-\beta \left(B^{\text{sp}}_{y-1}\right)^{\gamma}\right] e^{(\varsigma_y - (\sigma_R)^2/2)} \quad \text{(B2.4)}$$

and for the (standard) Beverton-Holt:

$$R_y = \frac{\alpha B_{y-1}^{sp}}{\beta + B_{y-1}^{sp}} e^{(\varsigma_y - (\sigma_R)^2/2)} \quad \text{(B2.5)}$$

where

α, β, and γ are spawning biomass-recruitment relationship parameters,

ς_y reflects fluctuation about the expected recruitment for year y, which is assumed to be normally distributed with standard deviation σ_R (which is input in the applications considered here); these residuals are treated as estimable parameters in the model fitting process.

B_y^{sp} is the spawning biomass at the start of year y, computed as:

$$B_y^{sp} = \sum_{a=1}^{m} f_a w_{y,a}^{strt} N_{y,a} e^{-Z_{y,a}\mu_{spawn}} \quad \text{(B2.6)}$$

because spawning for the cod stock under consideration is taken to occur three months (μ_{spawn} = 0.25) after the start of the year and some mortality has therefore occurred,

where

$w_{y,a}^{strt}$ is the mass of fish of age a during spawning, and

f_a is the proportion of fish of age a that are mature.

For RCp, the modified Ricker, with γ fixed to 1, has been used, i.e. the classical Ricker function.

B2.1.3. Total catch and catches-at-age

The total catch by mass in year y is given by:

$$C_y = \sum_{a=1}^{m} w_{y,a}^{mid} C_{y,a} = \sum_{a=1}^{m} w_{y,a}^{mid} N_{y,a} \; S_{y,a} F_y \left(1 - e^{-Z_{y,a}}\right) \Big/ Z_{y,a} \quad \text{(B2.7)}$$

where

$w_{y,a}^{mid}$ denotes the mass of fish of age a landed in year y,

$C_{y,a}$ is the catch-at-age, i.e. the number of fish of age a, caught in year y.

The model estimate of survey index is computed as:

$$B_y^{surv} = \sum_{a=1}^{m} w_{y,a}^{surv} S_a^{surv} N_{y,a} e^{-Z_{y,a} T^{surv}/12} \quad \text{(B2.8)}$$

for biomass indices and

$$N_y^{\text{surv}} = \sum_{a=1}^{m} S_a^{\text{surv}} N_{y,a} e^{-Z_{y,a} T^{surv}/12} \quad \text{(B2.9)}$$

for numbers indices

where

S_a^{surv} is the survey selectivity for age *a*, which is taken to be year-independent.

T^{surv} is the season in which the survey is taking place (T^{surv}=3 for spring surveys and T^{surv}=9 for fall surveys), and

$w_{y,a}^{surv}$ denotes the mass of fish of age *a* from survey *surv* year, taken as $w_{y,a}^{strt}$ for the spring survey and $w_{y,a}^{mid}$ for the autumn survey.

RCp is fitted to biomass indices.

B2.1.4. Initial conditions

As the first year for which data (even annual catch data) are available for the white hake stock considered clearly does not correspond to the first year of (appreciable) exploitation, one cannot necessarily make the conventional assumption in the application of SCAA's that this initial year reflects a population (and its age-structure) at pre-exploitation equilibrium. For the first year (y_0) considered in the model therefore, the stock is assumed to be at a fraction (θ) of its pre-exploitation biomass, i.e.:

$$B_{y_0}^{\text{sp}} = \theta \cdot K^{\text{sp}} \quad \text{(B2.10)}$$

with the starting age structure:

$$N_{y_0,a} = R_{\text{start}} N_{\text{start},a} \qquad \text{for } 1 \le a \le m \quad \text{(B2.11)}$$

where

$$N_{\text{start},1} = 1 \quad \text{(B2.12)}$$

$$N_{\text{start},a} = N_{\text{start},a-1} e^{-M_{a-1}} (1 - \phi S_{a-1}) \qquad \text{for } 2 \le a \le m-1 \quad \text{(B2.13)}$$

$$N_{\text{start},m} = N_{\text{start},m-1} e^{-M_{m-1}} (1 - \phi S_{m-1}) \big/ (1 - e^{-M_m} (1 - \phi S_m)) \quad \text{(B2.14)}$$

where ϕ characterises the average fishing proportion over the years immediately preceding y_0.

For RCp, θ and ϕ are estimated directly in the model fitting procedure.

B2.2. The (penalised) likelihood function

The model can be fit to (a subset of) survey abundance indices, and commercial and survey catch-at-age and catch-at-length data to estimate model parameters (which may include residuals about the stock-recruitment function, facilitated through the incorporation of a penalty function described below). Contributions by each of these to the negative of the (penalised) log-likelihood (- $\ell\text{n}L$) are as follows.

B2.2.1. Survey abundance data

The likelihood is calculated assuming that a survey biomass index is log normally distributed about its expected value:

$$I_y^{surv} = \hat{I}_y^{surv} \exp\left(\varepsilon_y^{surv}\right) \quad \text{or} \quad \varepsilon_y^{surv} = \ell n\left(I_y^{surv}\right) - \ell n\left(\hat{I}_y^{surv}\right) \qquad \text{(B2.15)}$$

where

I_y^{surv} is the survey index for survey *surv* in year *y*,

$\hat{I}_y^{surv} = \hat{q}^{surv} \hat{B}_y^{surv}$ is the corresponding model estimate, where

$\hat{q}^{surv}$ is the constant of proportionality (catchability) for the survey biomass series *surv*, and

ε_y^{surv} from $N\left(0, \left(\sigma_y^{surv}\right)^2\right)$.

The contribution of the survey biomass data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ell n\, L^{\text{survey}} = \sum_{surv} \sum_{y} \left\{ \ell n \left(\sqrt{\left(\sigma_y^{surv}\right)^2 + \left(\sigma_{Add}^{surv}\right)^2} \right) + \left(\varepsilon_y^{surv}\right)^2 / \left[2\left(\left(\sigma_y^{surv}\right)^2 + \left(\sigma_{Add}^{surv}\right)^2 \right) \right] \right\} \qquad \text{(B2.16)}$$

where

σ_y^{surv} is the standard deviation of the residuals for the logarithm of index *i* in year *y* (which are input), and

σ_{Add}^{surv} is the square root of the additional variance for survey biomass series *surv*, which is estimated in the model fitting procedure, with an upper bound of 0.5.

The catchability coefficient q^{surv} for survey biomass index *surv* is estimated by its maximum likelihood value:

$$\ell n\, \hat{q}^{surv} = 1/n_{surv} \sum_{y} \left(\ln I_y^{surv} - \ln \hat{B}_y^{surv} \right) \text{(B2.17)}$$

B2.2.3. Commercial catches-at-age

The contribution of the catch-at-age data to the negative of the log-likelihood function under the assumption of an "adjusted" lognormal error distribution is given by:

$$-\ell n\, L^{\text{CAA}} = \sum_{y} \sum_{a} \left[\ell n \left(\sigma_a^{com} / \sqrt{p_{y,a}} \right) + p_{y,a} \left(\ell n\, p_{y,a} - \ell n\, \hat{p}_{y,a} \right)^2 / 2\left(\sigma_a^{com}\right)^2 \right] \qquad \text{(B2.18)}$$

where

$p_{y,a} = C_{y,a} / \sum_{a'} C_{y,a'}$ is the observed proportion of fish caught in year *y* that are of age *a*,

$\hat{p}_{y,a} = \hat{C}_{y,a} / \sum_{a'} \hat{C}_{y,a'}$ is the model-predicted proportion of fish caught in year *y* that are of age *a*,

where

$$\hat{C}_{y,a} = N_{y,a} \; S_{y,a} F_y \left(1 - e^{-Z_{y,a}}\right) / Z_{y,a} \quad \text{(B2.19)}$$

and

σ_a^{com} is the standard deviation associated with the catch-at-age data, which is estimated in the fitting procedure by:

$$\hat{\sigma}_a^{com} = \sqrt{\sum_y p_{y,a} \left(\ell n \, p_{y,a} - \ell n \, \hat{p}_{y,a}\right)^2 / \sum_y 1} \quad \text{(B2.20)}$$

Commercial catches-at-age are incorporated in the likelihood function using equation (A1.18), for which the summation over age *a* is taken from age a_{minus} (considered as a minus group) to a_{plus} (a plus group).

In addition to this "adjusted" lognormal error distribution, some computations use an alternative "sqrt(p)" formulation, for which equation A1.18 is modified to:

$$-\ell \text{n} \, L^{\text{CAA}} = \sum_y \sum_a \left[\ell n \left(\sigma_a^{com}\right) + \left(\sqrt{p_{y,a}} - \sqrt{\hat{p}_{y,a}}\right)^2 / 2\left(\sigma_a^{\text{com}}\right)^2 \right] \quad \text{(B2.21)}$$

and equation A1.20 is adjusted similarly:

$$\hat{\sigma}_a^{com} = \sqrt{\sum_y \left(\sqrt{p_{y,a}} - \sqrt{\hat{p}_{y,a}}\right)^2 / \sum_y 1} \quad \text{(B2.22)}$$

This formulation mimics a multinomial form for the error distribution by forcing a near-equivalent variance-mean relationship for the error distributions.

B2.2.4. Survey catches-at-age

The survey catches-at-age are incorporated into the negative of the log-likelihood in an analogous manner to the commercial catches-at-age, assuming an "adjusted" lognormal error distribution (equation (A1.18)) where:

$p_{y,a}^{surv} = C_{y,a}^{surv} / \sum_{a'} C_{y,a'}^{surv}$ is the observed proportion of fish of age *a* in year *y* for survey *surv*,

$\hat{p}_{y,a}^{surv}$ is the expected proportion of fish of age *a* in year *y* in the survey *surv*, given by:

$$\hat{p}_{y,a}^{surv} = S_a^{\text{surv}} N_{y,a} e^{-Z_{y,a} T^{surv}/12} \Big/ \sum_{a'=1}^{m} S_{a'}^{\text{surv}} N_{y,a'} \, e^{-Z_{y,a'} T^{surv}/12} \quad . \quad \text{(B2.23)}$$

RCp uses the "adjusted log-normal" formulation for the error distribution of the commercial catch proportions-at-age and survey catch proportions-at-age.

B2.2.5. Survey catches-at-length

In some runs, catches-at-length are also incorporated in the likelihood function. These data are incorporated in the similar manner as the catches-at-age. When the model is fit to catches-at-length, the predicted catches-at-age are converted to catches-at-length:

$$\hat{p}_{y,l}^{surv} = \sum_a \hat{p}_{y,a}^{surv} A_{a,l}^{strt} \quad \text{(B2.24)}$$

for the spring survey, and

$$\hat{p}^{surv}_{y,l} = \sum_a \hat{p}^{surv}_{y,a} A^{mid}_{a,l} \qquad \text{(B2.25)}$$

for the fall survey,

where $A^{strt}_{a,l}$ and $A^{mid}_{a,l}$ are the proportions of fish of age a that fall in the length group l (i.e., $\sum_l A^{strt}_{a,l} = 1$ and $\sum_l A^{mid}_{a,l} = 1$ for all ages) at the beginning of the year and at the middle of the year respectively.

The matrices $A^{strt}_{a,l}$ and $A^{mid}_{a,l}$ are calculated under the assumption that length-at-age is normally distributed about a mean given by the von Bertalanffy equation, i.e.:

$$L^{strt}_a \sim N\left[L_\infty\left(1-e^{-\kappa(a-t_o)}\right);\left(\theta^{strt}_a\right)^2\right] \quad \text{(B2.26)}$$

for the spring survey and

$$L^{mid}_a \sim N\left[L_\infty\left(1-e^{-\kappa(a+0.5-t_o)}\right);\left(\theta^{mid}_a\right)^2\right] \quad \text{(B2.27)}$$

for the fall survey,

where

θ^{strt}_a and θ^{mid}_a are the standard deviation of begin and mid-year length-at-age a respectively, which are modelled to be proportional to the expected length-at-age a, i.e.:

$$\theta^{strt}_a = \beta\left[L_\infty\left(1-e^{-\kappa(a-t_o)}\right)\right] \quad \text{(B2.28)}$$

and

$$\theta^{mid}_a = \beta\left[L_\infty\left(1-e^{-\kappa(a+0.5-t_o)}\right)\right] \quad \text{(B2.29)}$$

with β an estimable parameter.

$L_\infty = 189\,cm$,

$\kappa = 0.0815\,yr^{-1}$,

$t_o = 0.0627\,yr$,

The following term is then added to the negative log-likelihood:

$$-\ell n\,L^{\text{CAL}} = w_{len}\sum_{surv}\sum_y\sum_l\left[\ell n\left(\sigma^{surv}_{\text{len}}/\sqrt{p^{surv}_{y,l}}\right) + p^{surv}_{y,l}\left(\ell n\,p^{surv}_{y,l} - \ell n\,\hat{p}^{surv}_{y,l}\right)^2/2\left(\sigma^{surv}_{\text{len}}\right)^2\right] \quad \text{(B2.30)}$$

The w_{len} weighting factor may be set to a value less than 1 to downweight the contribution of the catch-at-length data (which tend to be positively correlated between adjacent length groups because the length distributions for adjacent ages overlap) to the overall negative log-likelihood compared to that of the CPUE data.

RCp does not incorporate any catch-at-length data.

B2.2.6. Stock-recruitment function residuals

The stock-recruitment residuals are assumed to be log normally distributed. Thus, the contribution of the recruitment residuals to the negative of the (now penalised) log-likelihood function is given by:

$$-\ell n L^{\text{pen}} = \sum_{y=y_1+1}^{y_2} \left[\varepsilon_y^2 / 2\sigma_{\text{R}}^2\right] \quad \text{(B2.31)}$$

where

ε_y from $N\left(0,(\sigma_R)^2\right)$,

σ_{R} is the standard deviation of the log-residuals, which is input.

Equation B2.31 is used when the stock-recruitment curve is estimated internally. In some analyses reported in this paper where BRP estimates are based on stock-recruitment curves estimated "externally" using the assessment outputs, this "stock-recruitment" term is included for the last two years only, simply to stabilize these estimates which are not well determined by the other data. In these cases, the ε_y are calculated as the deviations from the mean log recruitment for the ten preceding years, i.e. recruitment estimates for 2010 and 2011 are shrunk towards the geometric mean recruitment over the preceding decade.

B2.2.7. Catches

$$-\ell n L^{\text{Catch}} = \sum_y \left[\frac{\ell n\, C_y - \ell n\, \hat{C}_y}{2\sigma_{\text{C}}^2}\right] \qquad \text{(B2.32)}$$

where

C_y is the observed catch in year *y*,

$\hat{C}_y$ is the predicted catch in year *y* (equation B2.7), and

σ_{C} is the CV input: 0.5 for pre-1964 catches, 0.3 for catches between 1964 and 1981 and 0.1 for catches from 1982 onwards.

B2.2.8 Incorporation of Bigelow vs Albatross survey calibration

The survey data provided are adjusted for the years 2009 to 2011 which were obtained from *Bigelow* surveys; these have been adjusted to "*Albatross* equivalents" through use of calibration factors estimated independently from paired tow experiments (Miller *et al*., 2010). However the survey data before and after the switch of vessels also provide information on the calibration factors because they sample the same cohorts. Incorporation of this information in assessments in this paper has been effected by treating the estimate with its variance as a form of "prior" which is effectively updated in the penalised likelihood estimation when fitting the model. The following contribution is therefore added as a penalty (or a prior in a Bayesian contact) to the negative log-likelihood in the assessment:

$$-\ln L^{calib} = (\Delta \ln \hat{q} - \Delta \ln q)^2 / 2\sigma_{\Delta \ln q}^2 \qquad \text{(B2.33)}$$

where

$\Delta \ln q = \ln(2.235)$ is the logged ratio of the catchability of the *Bigelow* to the *Albatross*, with standard error $\sigma_{\Delta \ln q} = 0.173 / 2.235$,

$\Delta \ln \hat{q}$ is the logged ratio of the catchabilities, estimated directly in the fitting procedure, where $q_{Big}^{Spr/Aut} = e^{\Delta \ln \hat{q}} q_{Alb}^{Spr/Aut}$.

In RCp, the calibration parameters are fixed to those estimated by Miller *et al*. (2010).

B2.3. Estimation of precision

Where quoted, CV's or 95% probability interval estimates are based on the Hessian.

B2.4. Model parameters

B2.4.1. Fishing selectivity-at-age:

For the NEFSC offshore surveys, the fishing selectivities are estimated separately for ages 1 to age 7. The estimated proportional decrease from ages 6 to 7 is assumed to continue multiplicatively to age 9+; this decrease parameter is bounded by 0, i.e. no increase is permitted.

The commercial fishing selectivity, S_a, is estimated separately for ages a_{minus} (1) to 6, and is taken to be flat thereafter. It is taken to differ over two periods: a) pre-1997, and b) 1998-present. The selectivities are estimated directly for each period.

B2.4.2. Other parameters

Stock-recruit standard dev.

σ_R 0.5

Model plus group

m 9

Commercial CAA

a_{minus}* 1

a_{plus} 7

Survey CAA		NEFSC spr	NEFSC fall
	a_{minus}*	1	1
	a_{plus}	7	7

Natural mortality

M 0.2 and age independent

Proportion mature-at-age

f_a input, see Table B65

Weight-at-age

$w_{y,a}^{strt}$ input, see Table B39b

$w_{y,a}^{mid}$ input, see Table B39a

Initial conditions for a 1963 starting year

θ estimated

ϕ estimated

* Strictly not a minus group anymore since the catches at age zero are ignored.

B2.5.Biological Reference Points (BRPs)

It is possible to estimate BRPs internally within the assessment by fitting the stock-recruitment relationship directly within the assessment itself. The F_{MSY} estimate is obtained by using a bisection routine to find where the derivative of the equilibrium catch vs F relationship has a zero derivative. This has to be based on point estimates, so that the estimate of other BRPs are conditional on this point estimate of F_{MSY}, with no Hessian based CV available for this quantity.

For some results reported here, however, the stock-recruitment relationships are fitted to the estimates of recruitment and spawning biomass provided by the various assessments to provide a basis to estimate BRPs. The rationale for estimation external to the assessment itself is to avoid assumptions about the form of the relationship influencing the assessment results. These fits are achieved by minimizing the following negative log-likelihood, where the $e^{-\frac{\sigma_R^2}{2}}$ term is added for consistency with equation A1.4, i.e. the stock-recruitment curves estimated are mean-unbiased rather than median unbiased:

$$-\ln L = \sum_{y=y1}^{2009} \left[\frac{\left(\ln(N_{y,1}) - \ln\left(\hat{N}_{y,1} e^{-\frac{\sigma_R^2}{2}} \right) \right)^2}{2\left((\sigma_R)^2 + (CV_y)^2 \right)} \right] \qquad \text{(B2.34)}$$

where

$N_{y,1}$ is the "observed" (assessment estimated) recruitment in year *y*,

$\hat{N}_{y,1}$ is the stock-recruitment model predicted recruitment in year *y*,

σ_R is the standard deviation of the log-residuals which is input (and set here to 0.5), and

CV_y is the Hessian-based CV for the "observed" recruitment in year *y*.

Note that the differential precision of the assessment estimates of recruitment is taken into account, and that the summation ends at 2009 because little by way of direct observation is as yet available to inform estimates of recruitment for 2010 and 2011.

Appendix B3
MCMC Analysis

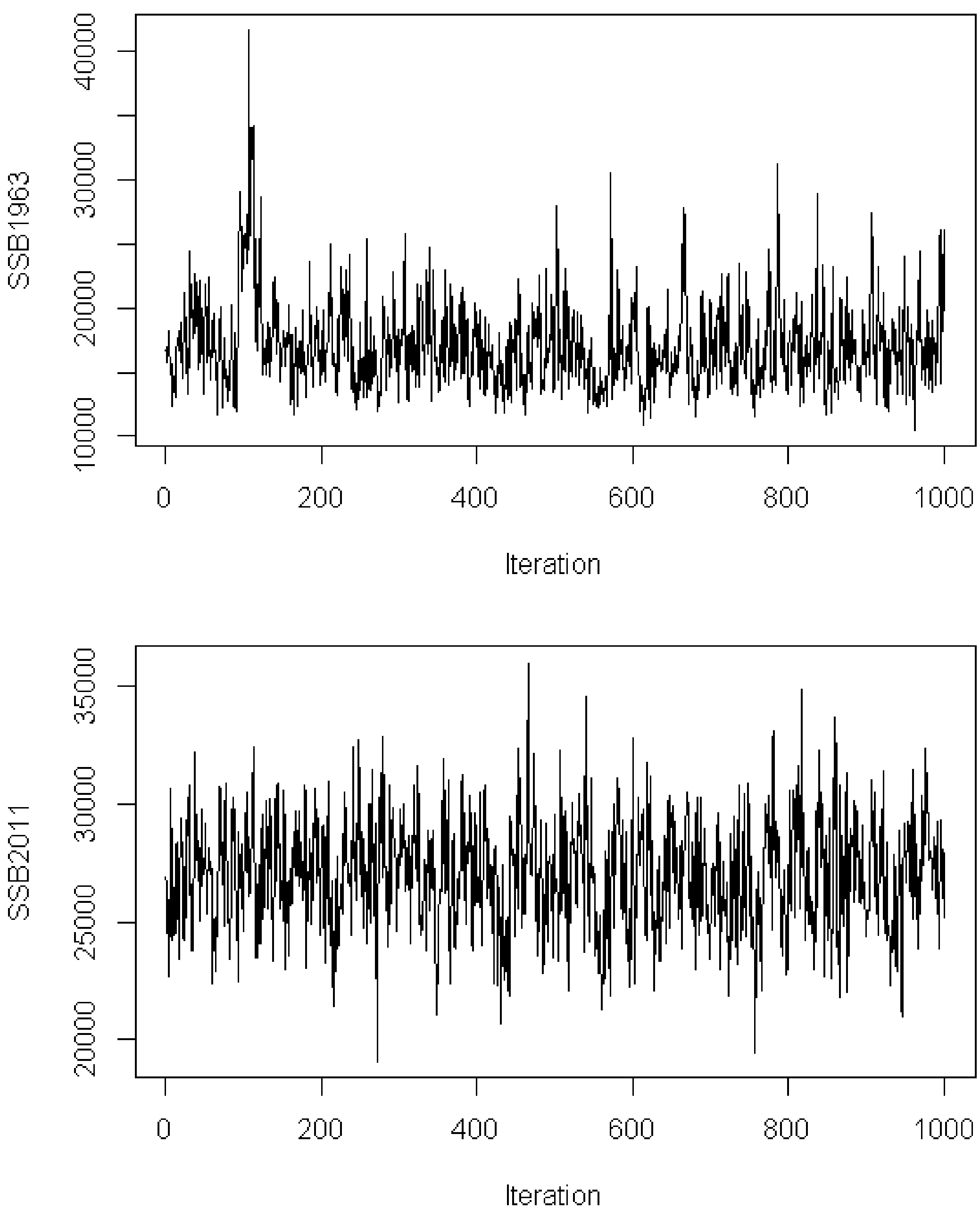


Figure Appendix B3.1a. Trace for SSB in 1963 (top) and 2011 (bottom) for the initial chain. The trace shows some indication of incomplete mixing at the beginning of the chain for the earlier SSB estimate.

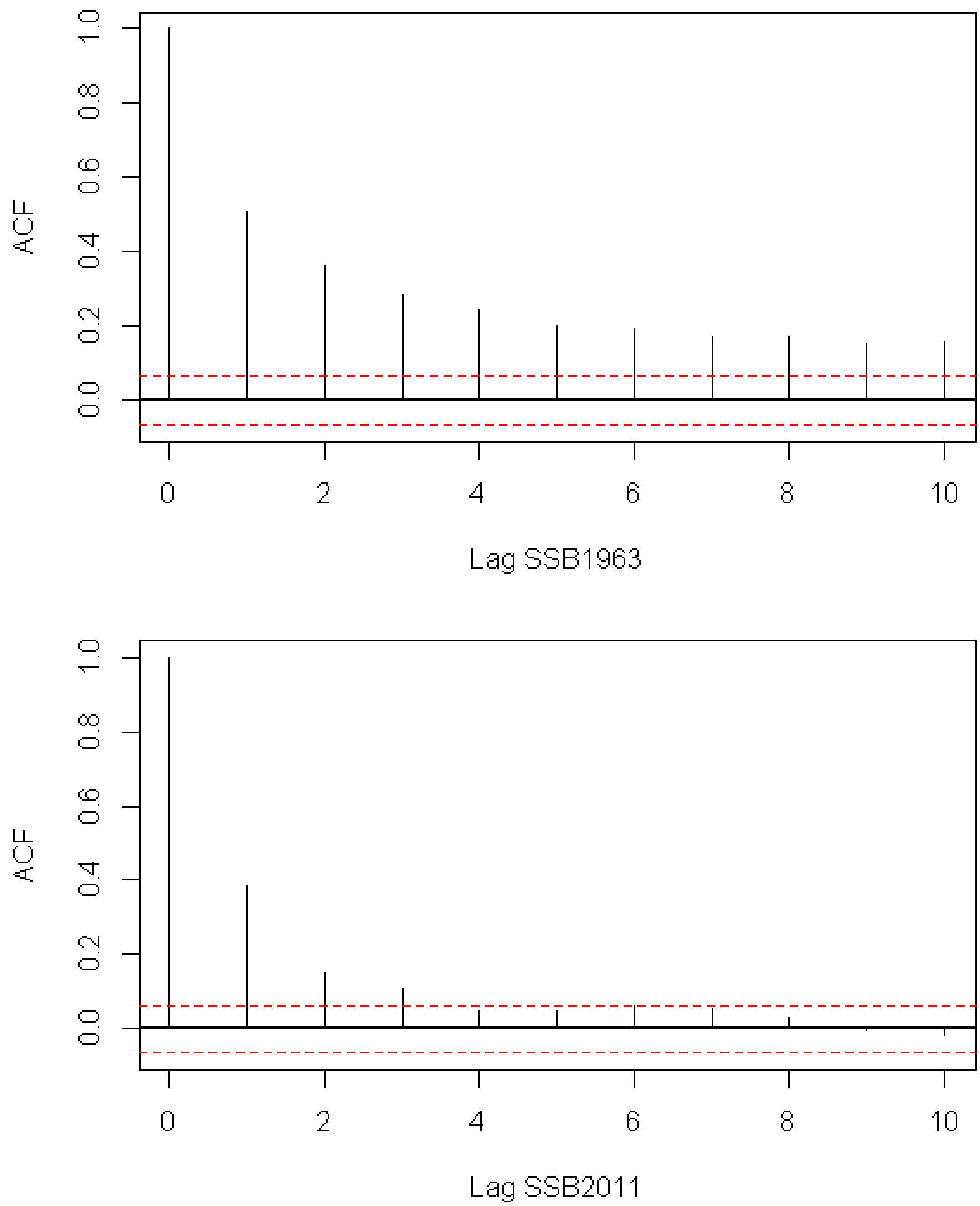
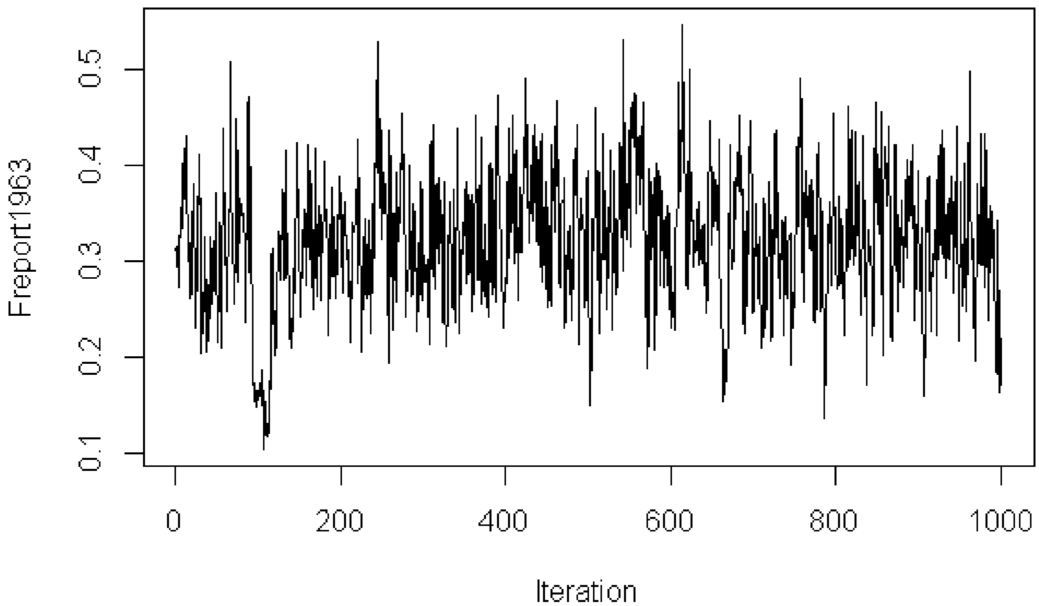


Figure Appendix B3.1b. Plot of autocorrelation within the initial chain of SSB in 1963 (top) and 2011 (bottom). This diagnostic suggests a much higher thinning rate is needed for the early estimates of SSB, while an addition thinning rate of 5 would probably suffice for more recent years.



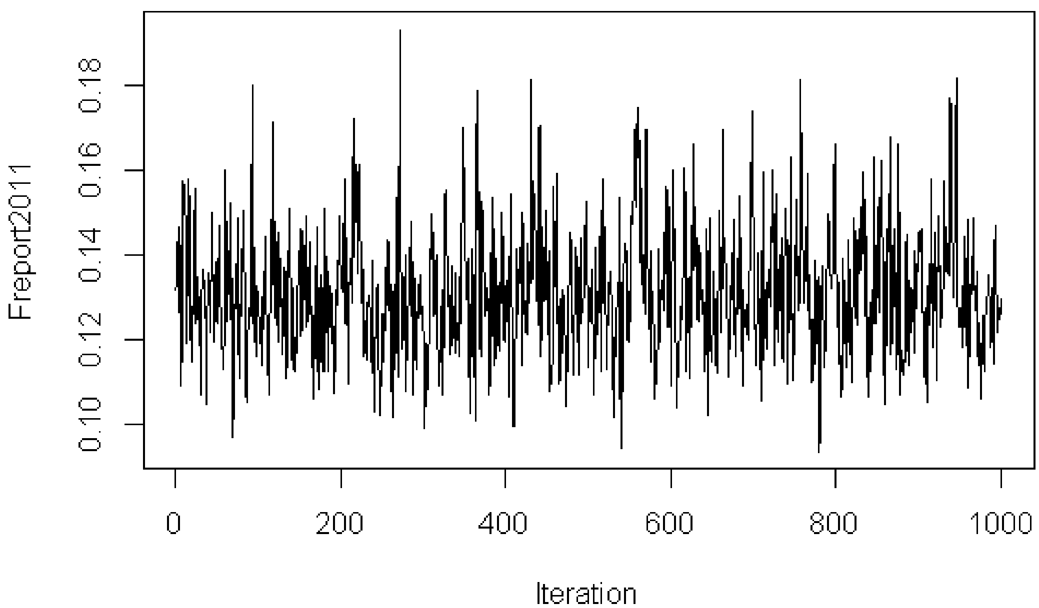
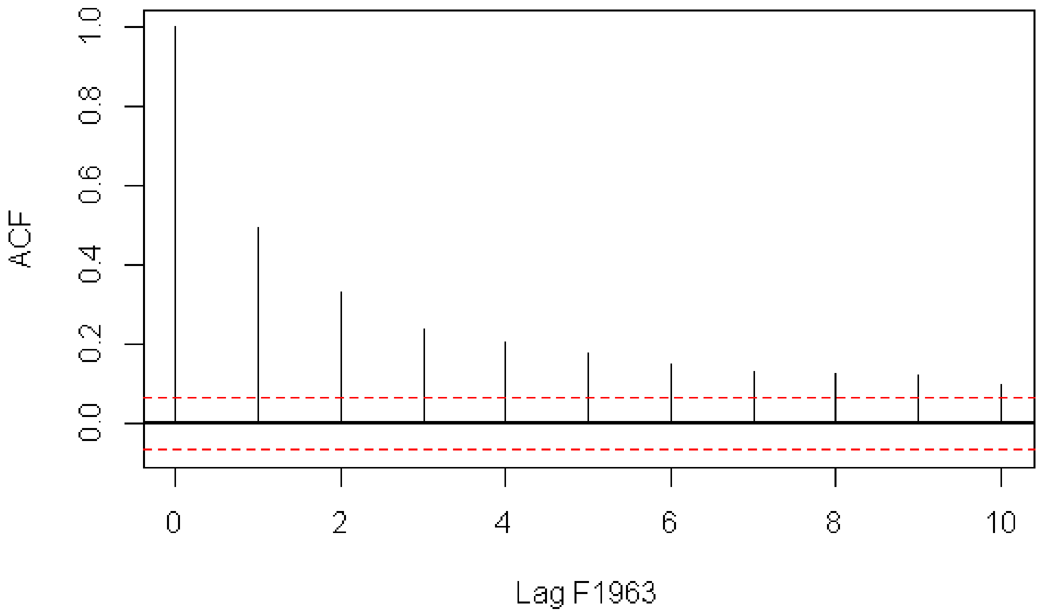


Figure Appendix B3.2a. Trace for Freport in 1963 (top) and 2011 (bottom) for the initial chain. The trace shows some indication of incomplete mixing at the beginning of the chain for the earlier Freport estimate. Freport is the full fishing mortality on age 6.



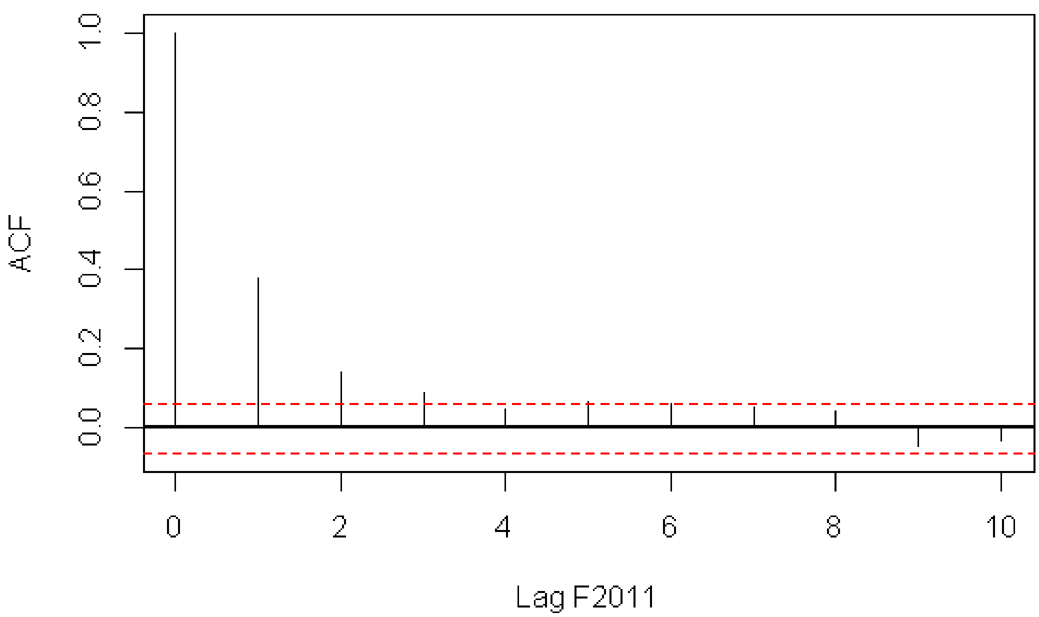


Figure Appendix B3.2b. Plot of autocorrelation within the initial chain of Freport in 1963 (top) and 2011 (bottom). This diagnostic suggests a much higher thinning rate is needed for the early estimates of Freport, while an addition thinning rate of 5 would probably suffice for more recent years.

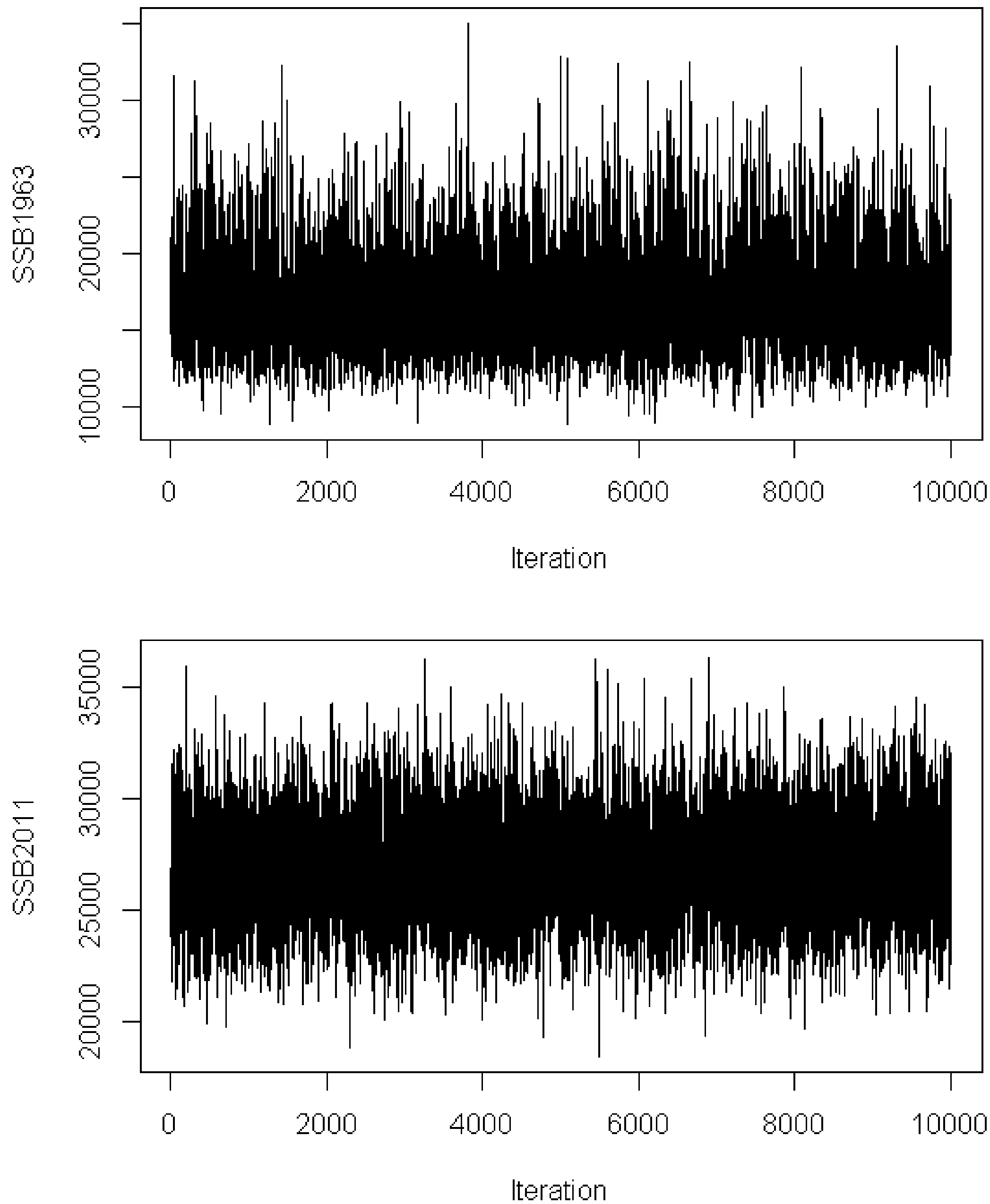


Figure Appendix B3.3a. Trace for SSB in 1963 (top) and 2011 (bottom) for the longer chain (10,000 iterations). The trace suggests adequate mixing.

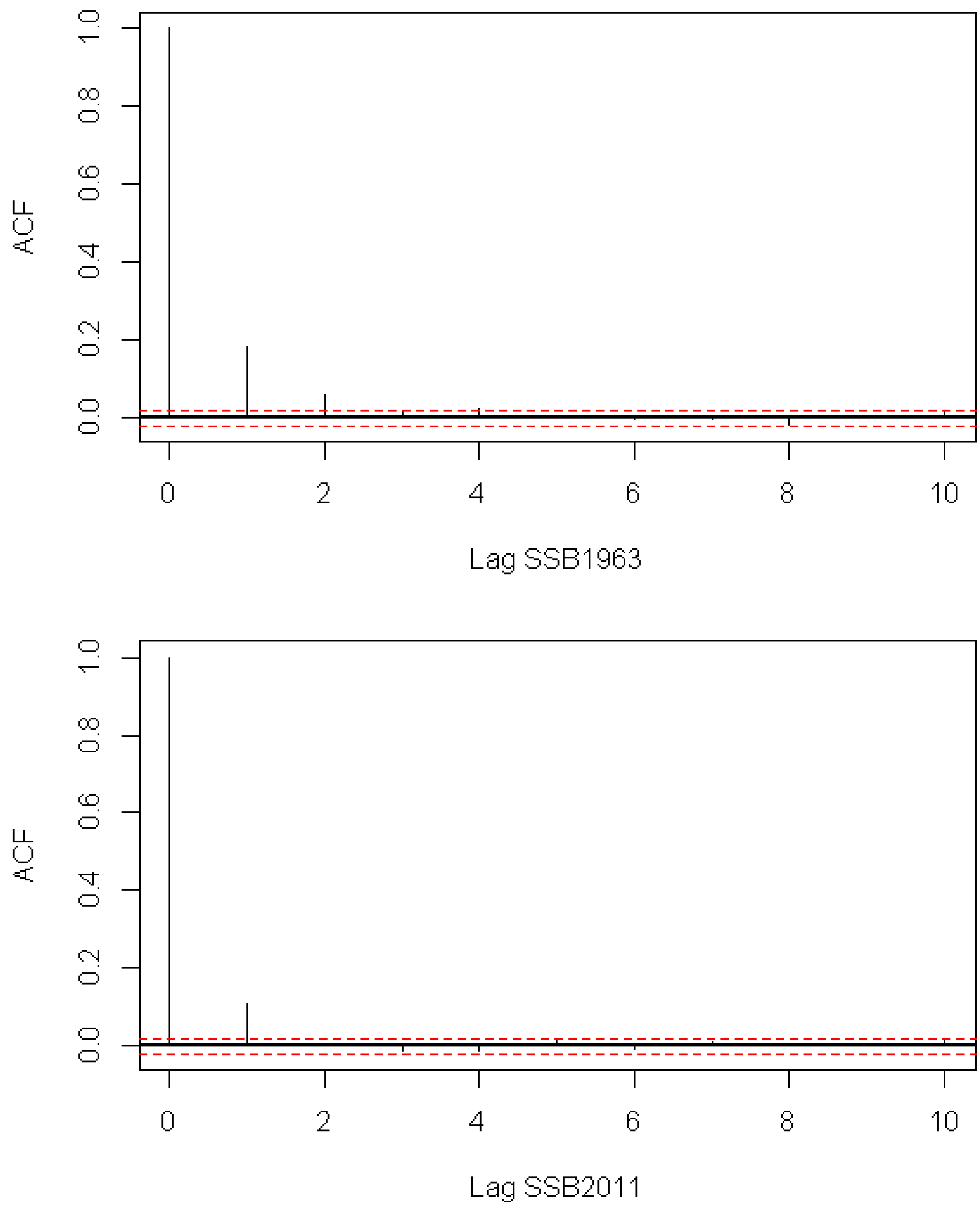


Figure Appendix B3.3b. Plot of autocorrelation within the longer chain (10,000 iterations) of SSB in 1963 (top) and 2011 (bottom). This diagnostic suggests a slightly higher thinning rate is needed for the estimates of SSB.

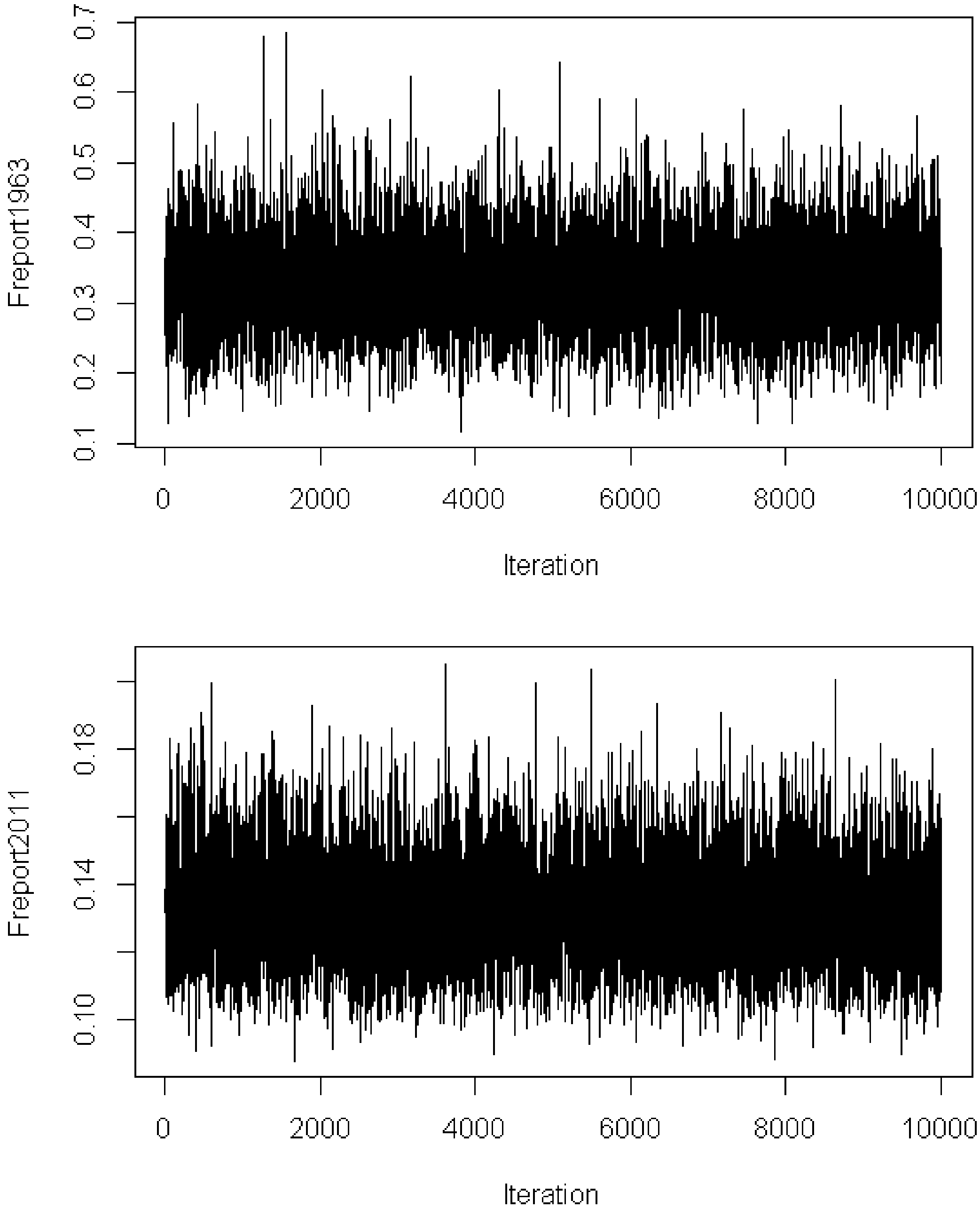
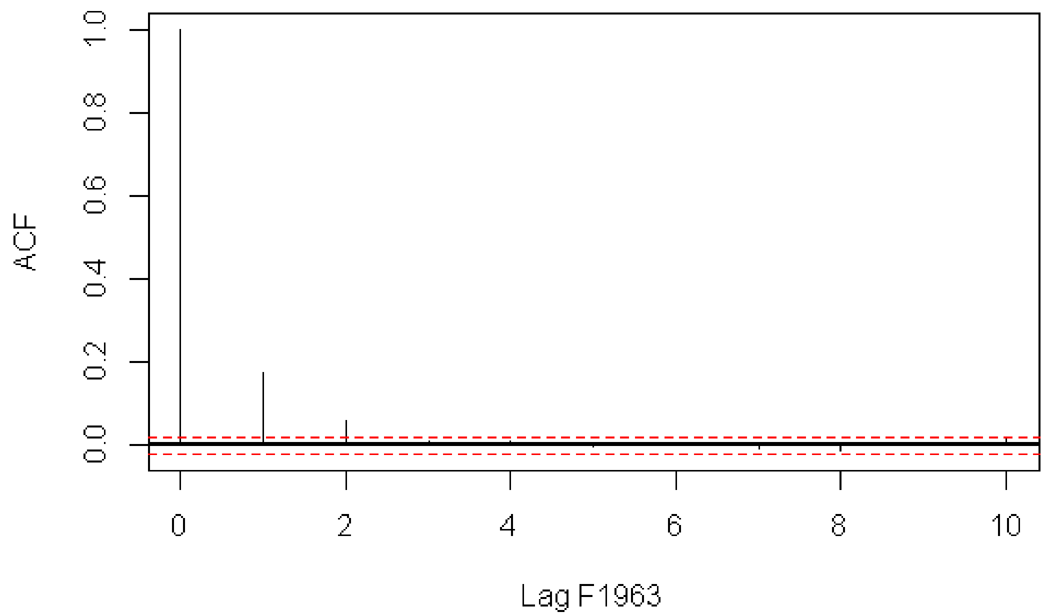


Figure Appendix B3.4a. Trace for Freport in 1963 (top) and 2011 (bottom) for the longer chain (10,000 iterations). The trace suggests adequate mixing.



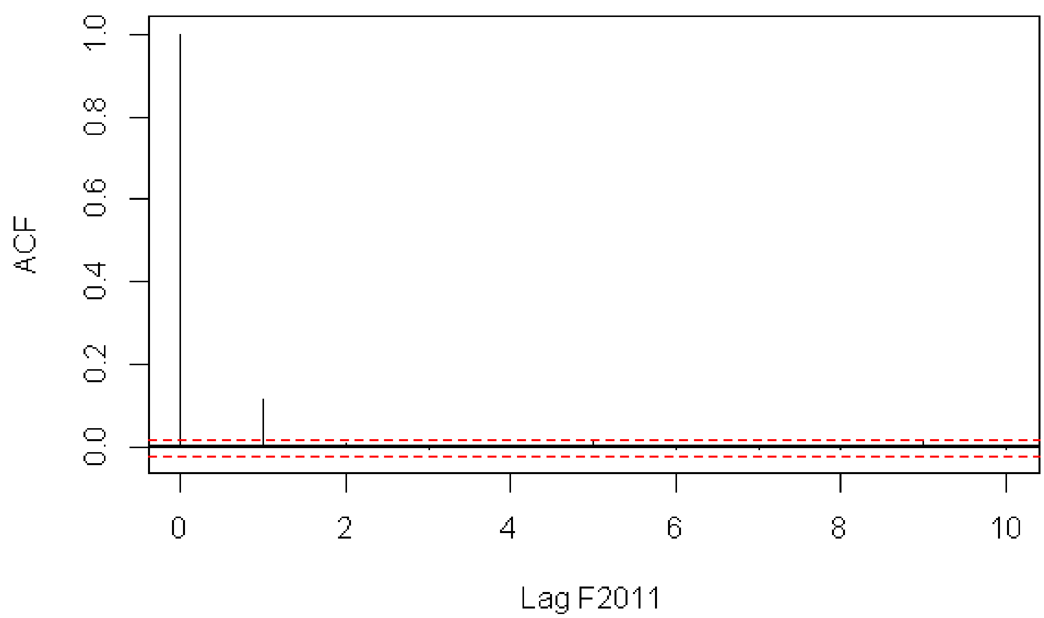


Figure Appendix B3.4b. Plot of autocorrelation within the longer chain (10,000 iterations) of Freport in 1963 (top) and 2011 (bottom). This diagnostic suggests a slightly higher thinning rate is needed for the estimates of Freport.

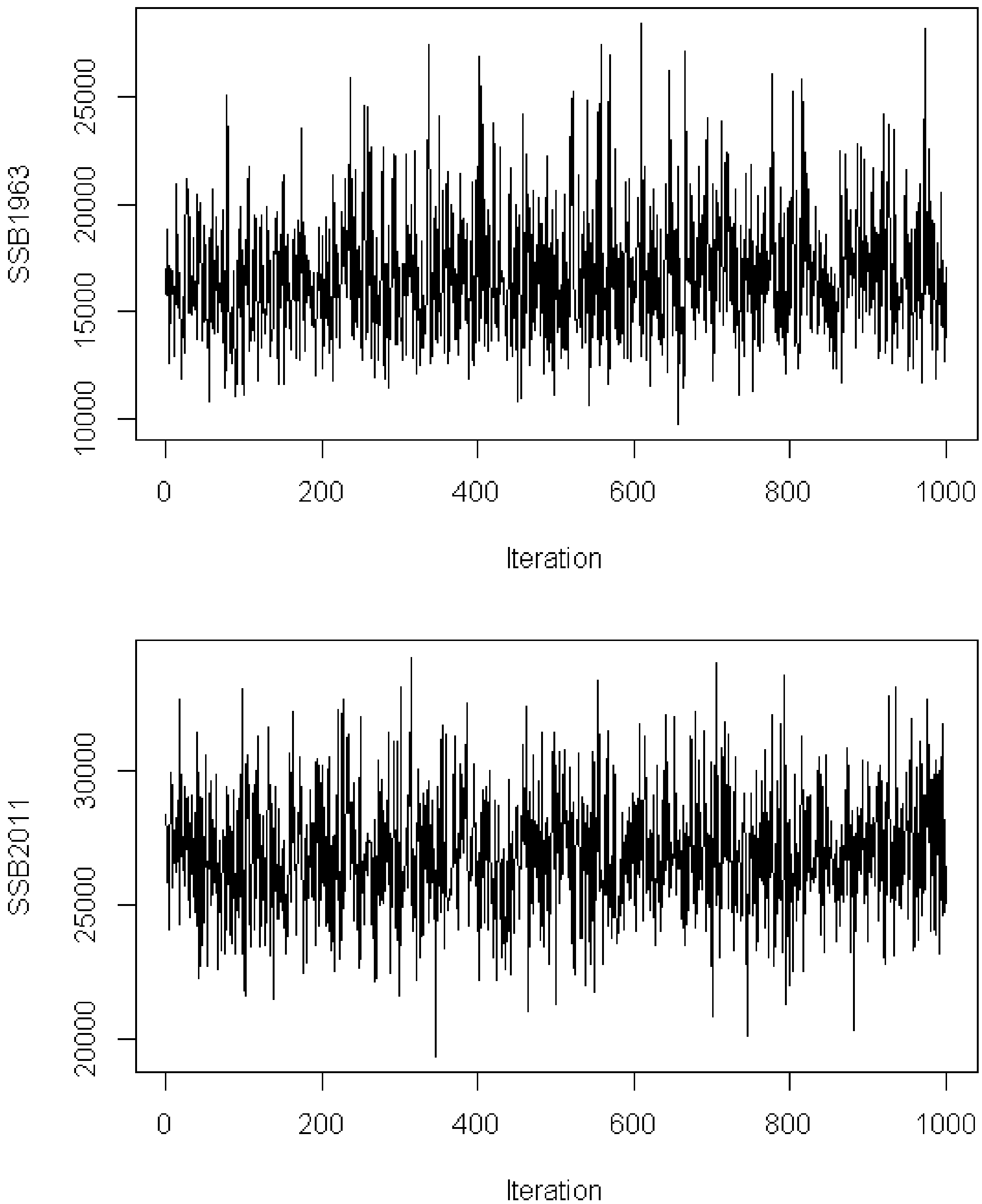
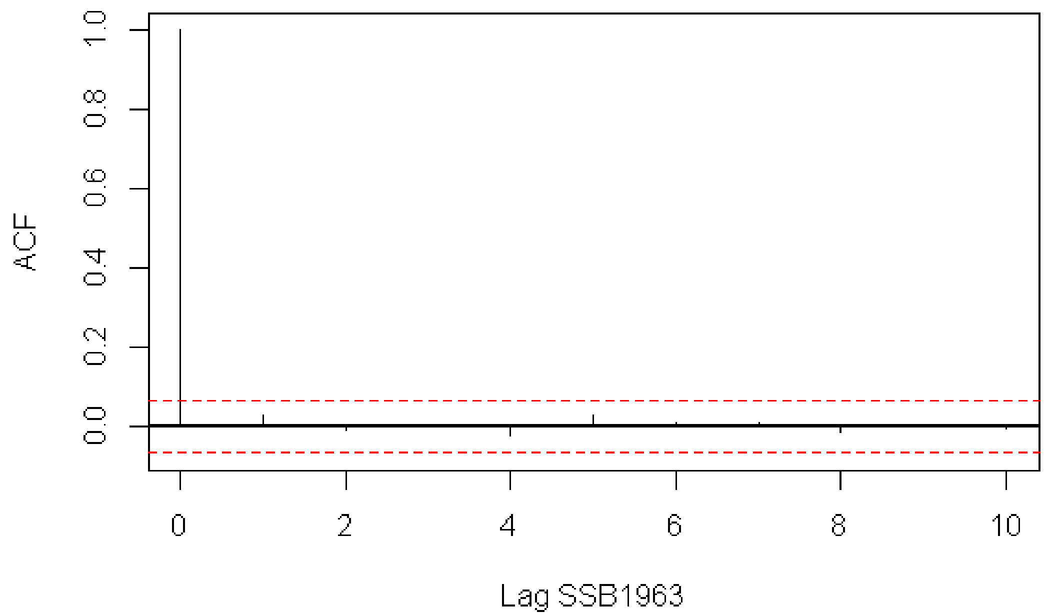


Figure Appendix B3.5a. Trace for SSB in 1963 (top) and 2011 (bottom) for the longer chain after burn-in and additional thinning (1,000 remaining iterations). The trace suggests adequate mixing.



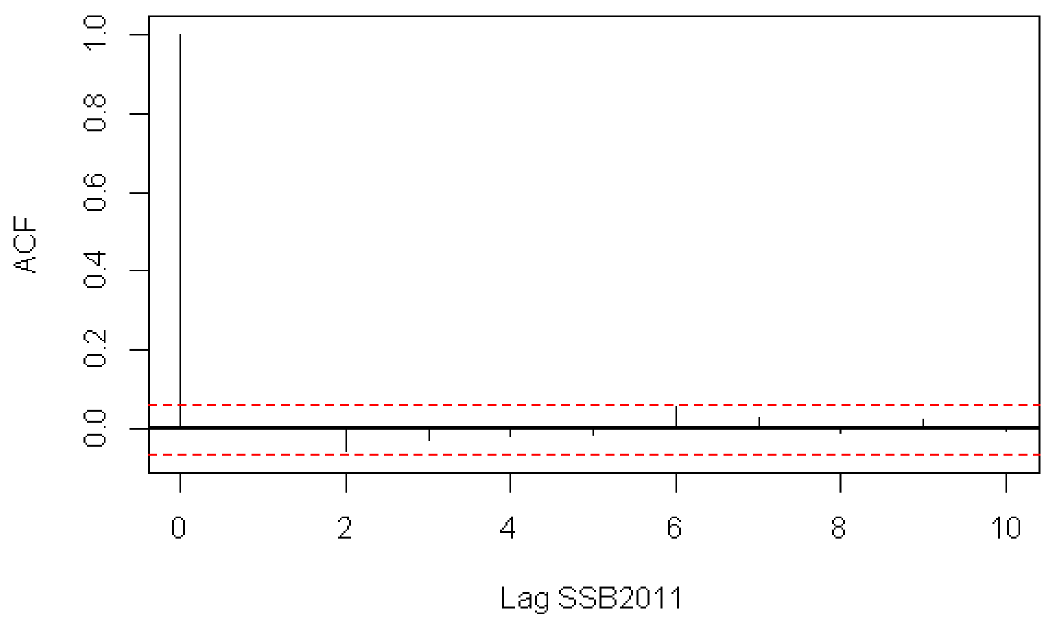


Figure Appendix B3.5b. Plot of autocorrelation within the longer chain after burn-in and thinning (1000 remaining iterations) of SSB in 1963 (top) and 2011 (bottom). This diagnostic suggests no additional thinning is needed.

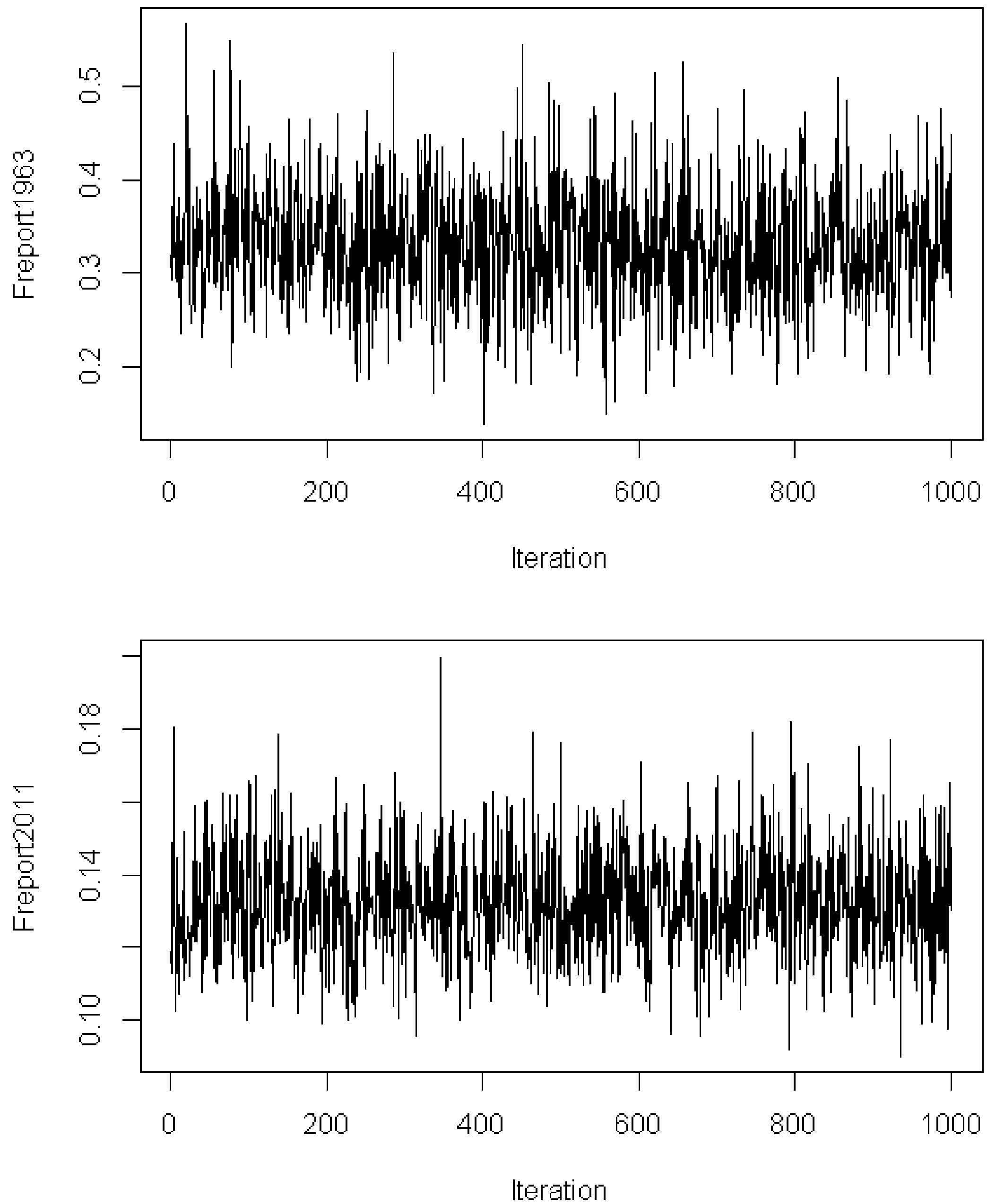
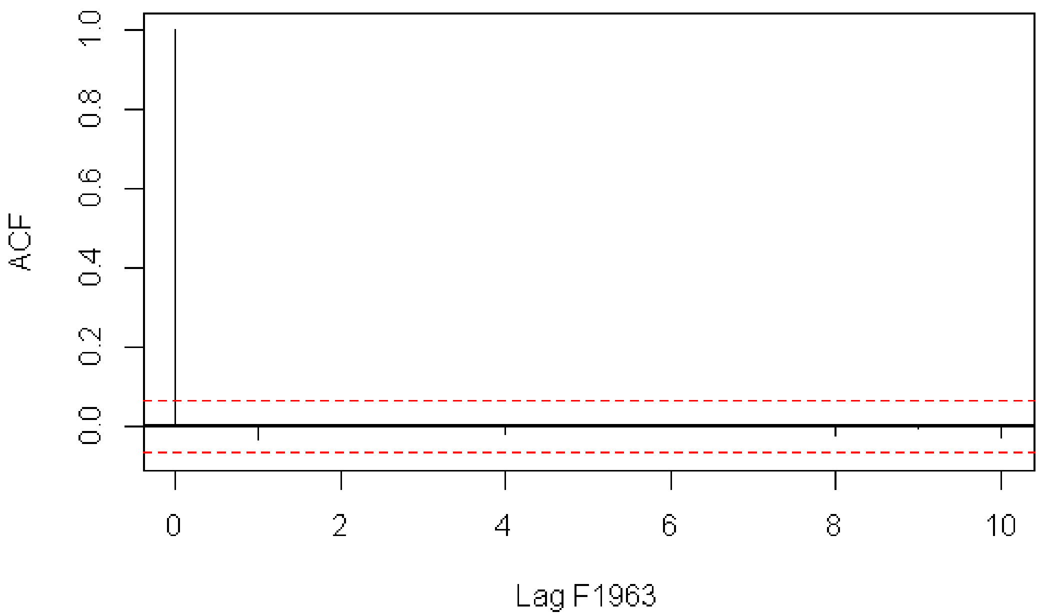


Figure Appendix B3.6a. Trace for Freport in 1963 (top) and 2011 (bottom) for the longer chain after burn-in and additional thinning (1,000 remaining iterations). The trace suggests adequate mixing.



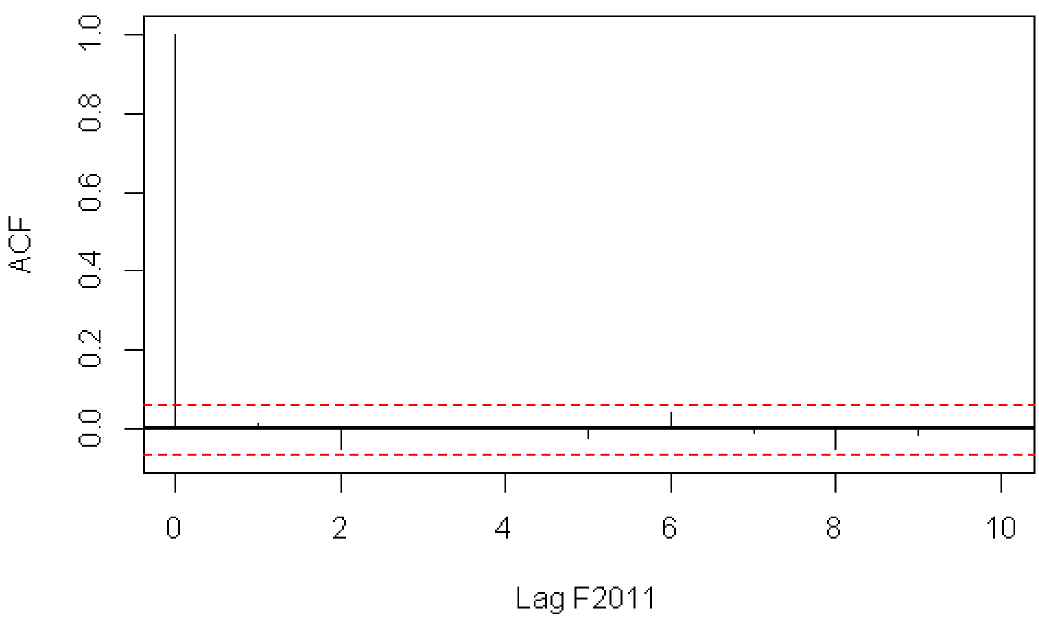


Figure Appendix B3.6b. Plot of autocorrelation within the longer chain after burn-in and thinning (1000 remaining iterations) of Freport in 1963 (top) and 2011 (bottom). This diagnostic suggests no additional thinning is needed.

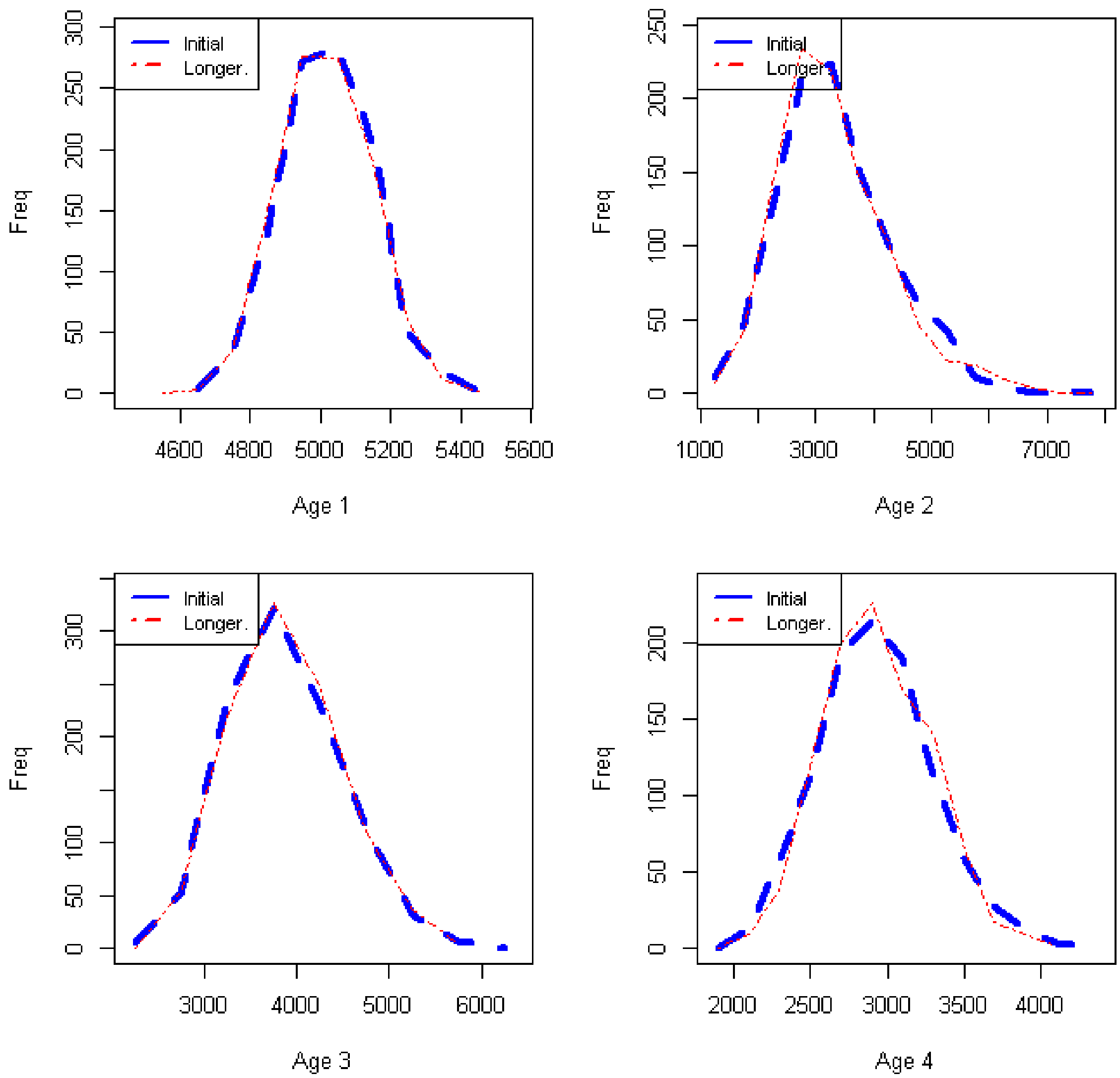


Figure Appendix B3.7. Comparison of distributions of numbers at age for the initial chain (200,000 thinned to 1000 iterations) and a longer chain (5 million, with burn-in and thinning to 1000 final iterations)

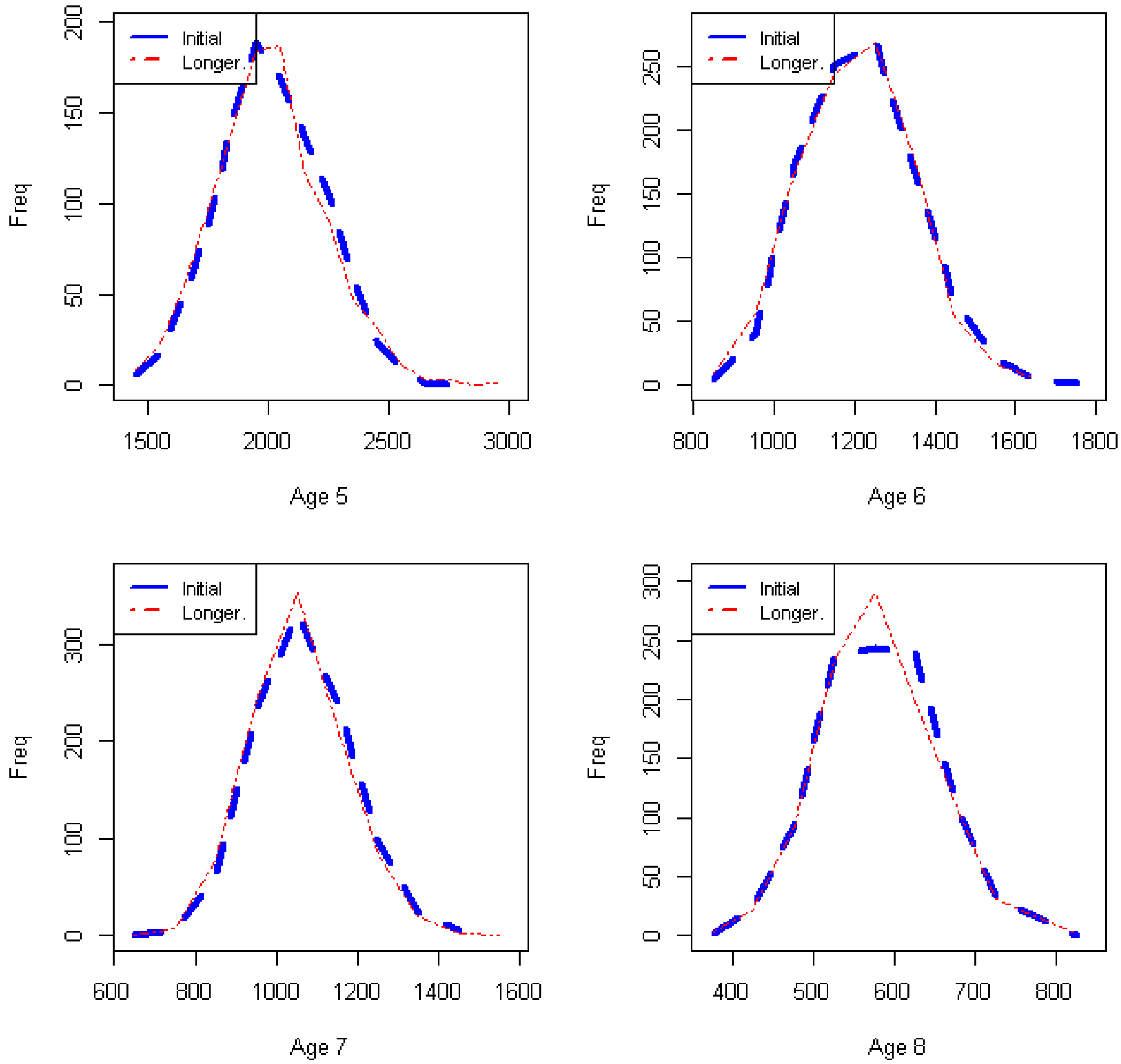


Figure Appendix B3.7 (cont.)

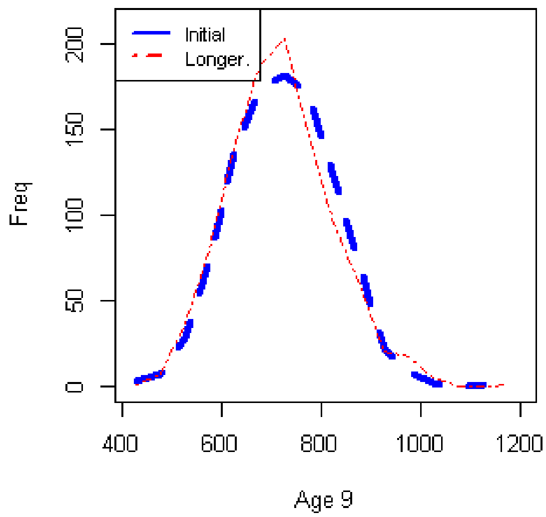
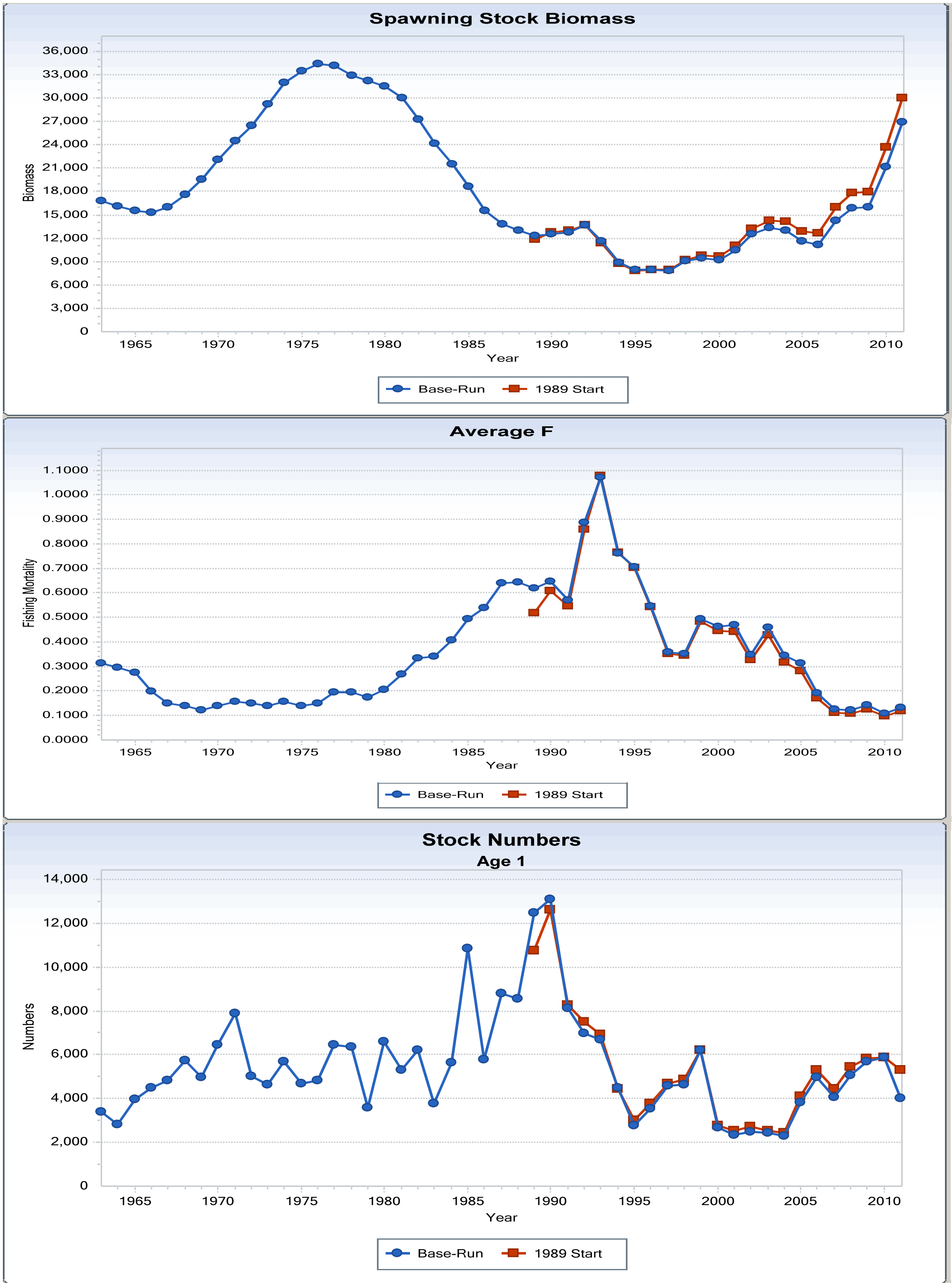
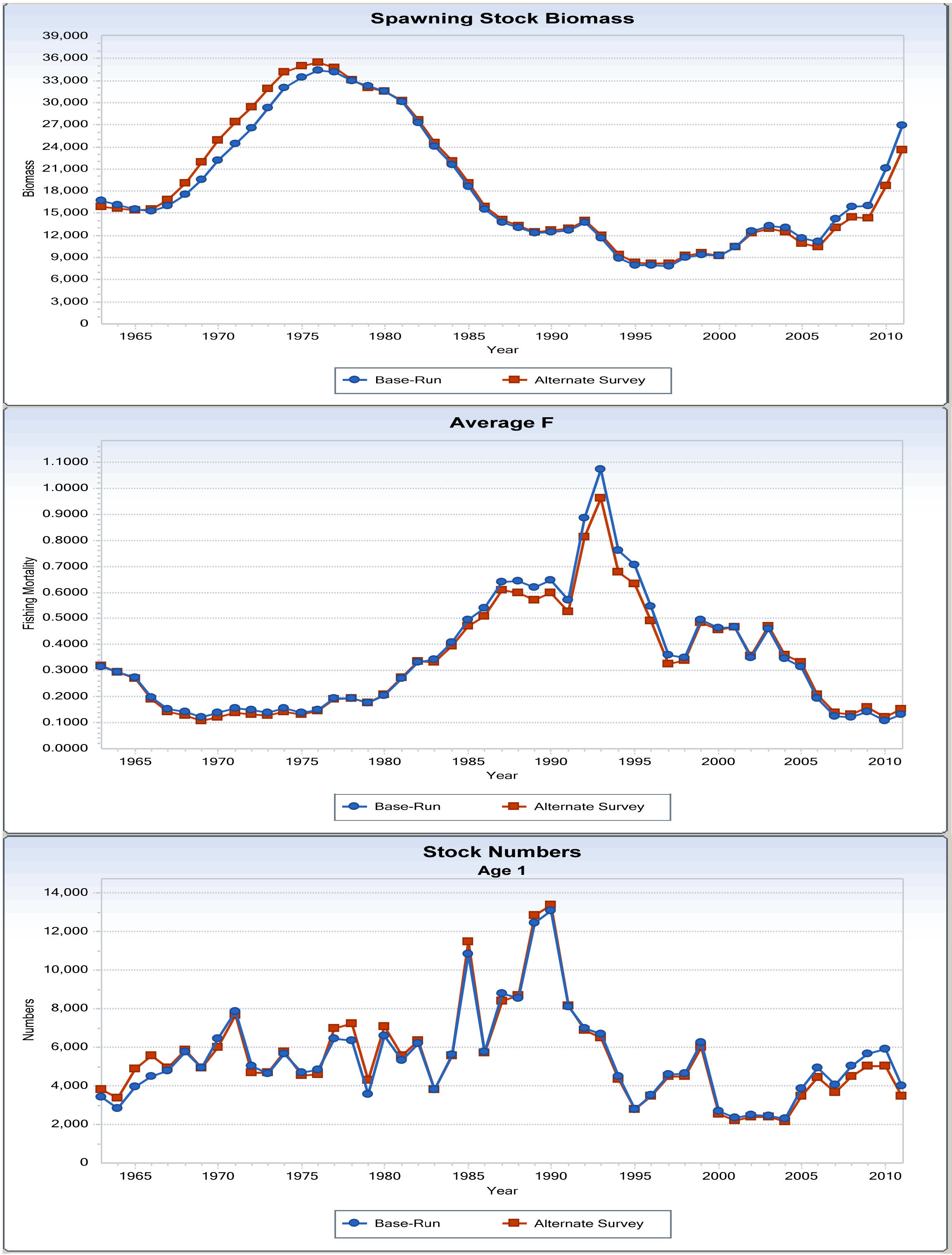


Figure Appendix B3.7 (cont.)

Appendix B4
ASAP sensitivity runs



Appendix Figure B4.1. Estimates of spawning stock biomass, fishing mortality and recruitment from a sensitivity run in which the starting year was changed from 1963-1982.



Appendix Figure B4.2. Estimates of spawning stock biomass, fishing mortality and recruitment from a sensitivity run in which the strata set used to calculate indices of abundance was changed from 01200-01300,01360-01400 (Base-Run) to 01010-01300,01360-01400 (Alternate Survey).

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